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Understanding of Active and Passive Constructions in 7- to 10-Year-Old Russian-Speaking Children: Reliance on Inflections or Word Order

Tatiana V. Akhutina[a*], Yana R. Panikratova[a,c], Alexey A. Korneev[a], Ekaterina Yu. Matveeva[a], Rosa M. Vlasova[b]

[a] *Lomonosov Moscow State University, Moscow, Russia*

[b] *University of North Carolina at Chapel Hill, USA*

[c] *Mental Health Research Center, Moscow, Russia*

* Corresponding author. E-mail: akhutina@mail.ru

Background. The background of the present study includes analysis of the understanding of active and passive grammatical constructions (GCs) in Russian-speaking aphasic patients and in children aged 3, 4 and 5 years (Akhutina, 1989; Akhutina, Velichkovskiy, & Kempe, 1988). Data regarding the reorganization of the children's strategies are further compared to GC understanding in children speaking different languages, and their interpretations.

Objective. To analyze the variable mechanisms of understanding of reversible GCs in primary-school-age children, namely, to reveal individual differences in reliance on word order or case endings.

Design. Ninety-three first-graders, 93 second-graders, and 63 third-graders underwent a neuropsychological assessment and computer-based sentence-to-picture test of their understanding of reversible GCs of active/passive voice with direct/reverse word order. The "productivity" of understanding GCs (percent of correct responses) was analyzed through cluster analysis.

Results. The cluster analysis divided the children into four clusters. Cluster 1 consisted of eight children with low productivity, who were excluded from further analysis. Cluster 2 was characterized by low productivity in passive direct constructions (Group 1); Cluster 3 comprised children who had low productivity in passive reverse sentences (Group 2). Cluster 4 included children with good understanding of all GCs (Group 3). Between-group differences in productivity and time of correct responses in GCs, as well as neuropsychological indexes, were revealed.

Conclusion. The results are consistent with the following hypotheses: (a) Group 1 relies on the rule "The first noun is the agent", whereas the other two groups use morphological marking; (b) Group 1 is the weakest neuropsychologically, and syntactic understanding processes involve a more diffuse activation of the brain in this group, compared to more successful children; (c) changes in response times from the first to the second grade are under the influence of cerebral changes induced by reading acquisition.

Keywords: neuropsychology, individual differences, comprehension, grammatical constructions, children

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Introduction

The present study has a considerable background, linked to researching the mechanisms of syntax production and comprehension in models of aphasia and language acquisition. In the 1970s, T.V. Akhutina was investigating syntactic deficits in patients with Broca's aphasia. In a longitudinal study of reverse development of syntactic aphasia symptoms, she revealed three variants of syntactic disorders, differing in severity. A telegraphic style, the most severe variant of agrammatism, was characterized by combining words according to the pragmatic principle: "Rain child tree", "Radio weather rain". After that, patients began to use the rule of word order, making self-corrections like "Dinner…bread…no…mother bread…", and generating contrast pairs: "I went neighbors, neighbors…went I". Then these patients began to use regular marking of a direct object with inflections or even prepositions (notably, earlier marking was random). In some patients, this was followed by overgeneralization of marking: "Mother washed in a boy". After this, the set of surface rules slowly increased.

Combined research into the understanding of reversible active as well as passive grammatical constructions (GCs) in patients with medium and mild agrammatism variants demonstrated clear differences in understanding these types of GCs (Akhutina, 1979, 1989). Let us dwell on the method and the materials of these studies, because they were used in later research, including the current study.

In a sentence-to-picture test, patients were shown two pictures and had to choose the one relevant to the sentence they had heard. GCs can be divided into four types (see Table 1).

Table 1

The syntactic constructions used in the test

Type of sentence	Surface structure	Roles order	Examples
Active with direct word order (AD)	SVO	Agent-Patient	Anna spasla Pet'u (Accus. case) Ann saved Pete
Active with reverse word order (AR)	OVS	Patient-Agent	Pet'u (Accus. case) spasla Anna Pete (Accus. case) saved Ann
Passive with direct word order (PD)	SVO	Patient-Agent	Pet'a spasen Annoy (Instr. case) Pete was saved by Ann
Passive with reverse word order (PR)	OVS	Agent-Patient	Annoy (Instr. case) spasen Pet'a By Ann was saved Pete

Note: S = subject, V = verb, O = object.

Patients with the medium variant of agrammatism gave the right answers for active direct (AD), active reverse (AR), passive direct (PD), and passive reverse (PR) in 92, 50, 32, and 79 percent of cases, respectively; patients with milder agrammatism responded accurately in 97, 89, 81, and 63 percent of cases. This means that the patients who relied on word order in language production used the rule "The first noun is the agent" in comprehension as well (the agent is in the first place in

AD and PR). In contrast, the patients who had begun using inflections in language production considered inflections also.

Comparative research into GC understanding in patients with other aphasia types showed pronounced difficulties in patients with semantic aphasia. They gave the right answers in 88, 78, 54, and 61 percent of cases for AD, AR, PD, and PR respectively. A.R. Luria explained such problems by "the disturbances of internal 'quasi-spatial' synthesis" (Luria, 1973). A similar interpretation and discussion of contemporary data can be found in the study of Thothathiri, Kimberg, and Schwartz (2012).

Difficulties in GC understanding in patients with acoustic-mnestic aphasia depended on aphasia severity and oral or written presentation of sentences, which pointed to a dependency of GC understanding on the possibility of sentence perception and retention in memory. Therefore, this deficit was secondary, not directly linked to syntactic difficulties (Akhutina, 1989). Similar data were found by Dragoy et al. (2015) for the other type of GCs.

To compare the mechanisms of syntax acquisition in normal children and its disintegration in aphasia, we carried out a study of the understanding of GCs in children aged from 3 to 5 years (Akhutina, 1989; Akhutina, Velichkovskiy, & Kempe, 1988; Kempe, 1985), with the same method.

The results were similar for 3- and 5-year-olds, namely the response productivity decreased from AD to PR: 78, 75, 42, 39 percent of correct answers in 3-year-old children and 100, 81, 69, and 61 percent in 5-year-olds.

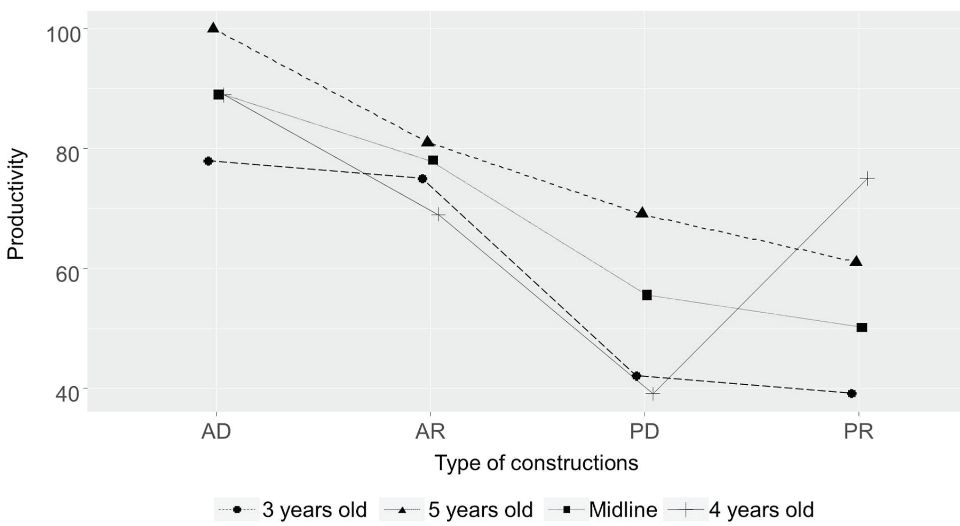

Figure. 1. Productivity (percent of correct responses) in GCs of four types in the 3-, 4- and 5-year-olds.

A different picture was seen in 4-year-olds: 89, 69, 39, and 75 percent of answers were correct. If we draw a midline between the results of 3- and 5-year-olds and compare it to the results of 4-year-olds, we find that results in AD lie on this line; results in AR and particularly in PD are much worse than expected; and results in PR are much better than expected (see Fig.1). These children are relying on the rule "The first noun is the agent", which was interpreted as a sign of the prevailing semantic-syntactic strategy in understanding reversible constructions in the majority of 4-year-olds.

Notably, these data reflected not the common results for children of a particular age, but results of the leading groups (55, 73, and 88 percent in 3-, 4-, and 5-year-olds, respectively). Thus, we found that 73% of 4-year-olds used the rule "The first noun is the agent", while 88% of 5-year-olds used syntactic rules close to adult rules. We suggested that older children would rely on adult rules. However, this suggestion turned out to be wrong. A. Statnikov found that a significant number of first-graders (7-year-olds), and especially children with speech disorders, understood reverse passive GCs better than direct GCs (Statnikov, 2015; Statnikov & Akhutina, 2013).

We decided to verify these data through studying first-, second-, and third-graders. But before we turn to the methodology and results of our current study, let us discuss the results from study of other languages and their interpretation.

Studies of the understanding of active and passive GCs in children (matching a sentence to one of two pictures or manipulating with toys in act-out tests) have been ongoing for 50 years (Bever, 1970; Hakuta, 1982; MacWhinney & Bates, 1989; MacWhinney, Pléh, & Bates, 1985; Pléh, 1981; Slobin, 1966; Slobin & Bever, 1982). One of the earliest studies summed up the results of understanding reversible GCs in the following way: "Two-year-olds understand transitive active sentences, three-year-olds understand many passive sentences. Older children understand some sentences less well than younger children. This brief decrease in comprehension ability is due to the temporary overgeneralization of perceptual strategies which are drawn from the child's experience" (Bever, Mehler, & Valian, 1968, p. 3). Bever (1970) described this strategy as follows: "Any Noun–Verb–Noun (NVN) sequence within a potential internal unit in the surface structure corresponds to 'actor–action–object' " (p. 22).

The decreased understanding of passive GCs in 4-year-olds was confirmed in many further studies of children acquiring different languages (Hakuta, 1982; MacWhinney & Bates, 1989; MacWhinney, Pléh, & Bates, 1985; Pléh, 1981; Slobin & Bever, 1982). Bever et al. (1968) suggested the following interpretation of syntax mechanisms before, during and after overgeneralization: "(1) Dependence on basic perceptual and conceptual mechanisms, (2) extension of those basic mechanisms by generalization drawn from experience, and (3) the development of a broad conceptual base which mediates between the basic mechanisms and generalization" (p. 3).

Let us compare this hypothesis to the later point of view regarding the reorganization of representations in linguistic and cognitive domains within the model of representational redescription (RR model) by A. Karmiloff-Smith (1995). According to the RR model, development involves three recurrent phases. During the first phase, the child focuses on external data and achieves a relatively successful performance. In the second phase, the child is no longer focusing on the external data, and the internal representations begin to be changed. Finally, during the third phase, internal representations and external data are reconciled, and, regarding language, a new mapping is made between input and output representations in order to restore correct usage. With the help of these reiterated phases, the child moves from one level of language acquisition to the next, and the format of the internal representations changes from an implicit level to explicit levels (E1, E2, E3). At the implicit level, information is encoded in a procedural form and new representations are independently stored. The representations are bracketed, so a procedure as a whole is available as data to other operators; however, its component parts are not, and hence no intra-domain or inter-domain information can yet be formed. Karmiloff-Smith notes that the implicit representations remain intact in the child's mind and can be called up later for particular goals that require speed and automaticity. The E1 representations are reduced descriptions that lose many details of the procedurally encoded information, and at the same time they are more cognitively flexible and can be manipulated and related to other re-described representations. However, they are not available to conscious access and the verbal report that is possible at levels E2 and E3. In the conclusion of her description of the RR model, Karmiloff-Smith notes that there are multiple levels at which the same knowledge is represented, and underlines that the notion of multiple encoding is important for our understanding of the workings of the human mind and brain.

Karmiloff-Smith's RR model corresponds to many findings in language acquisition research and aphasiology. We can mention first of all the usage-based theory of language acquisition, proposed by M. Tomasello (2009), according to which a child learns language from actual "usage events," i.e., from particular utterances in particular contexts, and builds up increasingly complex and abstract linguistic representations from these (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008). This means that initial representations might be tied to the specific sentence-level properties of high-frequency events, including information about their prototypical semantic roles and animacy characteristics (Ambridge, Kidd, Rowland, & Theakston, 2015; Buckle, Lieven, & Theakston, 2017). We can also mention the dissociation of voluntary and involuntary speech/language processes in aphasia patients (Luria, 1970).

In terms of the RR model and the usage-based theory of language, it is easy to interpret the results of the language comprehension test in Russian-speaking 3- to 5-year-old children, described earlier. According to the RR model and the usage-based theory of language acquisition, at the first stage, 3-year-olds demonstrate procedures that were acquired independently of each other; the more frequently they were present in input, the better they are acquired. There are no general rules that combine all constructions; all of them are holistic gestalts ("bracketed representations"). Inner analysis of these procedures (the second phase, according to Karmiloff-Smith) leads to distinguishing the general, most regular pattern: A noun with the diffuse semantic-syntactic meaning of an agent takes the first place in an NVN sequence. The less reinforced the previous procedural knowledge, the greater the effect of the new rule (compare to Dittmar, Abbot-Smith, Lieven, & Tomasello, 2014). We can see the biggest changes in understanding of the reverse passive (such GCs are very rare), then in the direct passive (they are rare constructions), then the reverse active (they are not so rare constructions). During the understanding of direct active constructions, old and new rules converge, and only the expected age-related changes are revealed (results of 4-year-olds constitute a mean between results of 3- and 5-year-olds). In general, a system of processing keeps both old and new rules, competing or converging with each other. The general consequence of stages in acquiring rules of understanding active and passive constructions can be observed in the comparison of our data to data of German-speaking children, because the German language also contains GCs with direct and reverse word orders. Two-year-olds correctly understood only sentences with both cues supporting each other – the prototypical form. Five-year-olds were able to use word order by itself, but not case markers. Only 7-year-olds behaved like adults by relying on case markers over word order when the two cues conflicted (Dittmar et al., 2008). The authors suggest that their findings demonstrate that prototypical instances of linguistic constructions with redundant grammatical marking play a special role in early acquisition (notably, that repeatability of prototypical constructions improves their primary acquisition on the level of procedural rules) and only later are children able to isolate and weigh individual grammatical cues appropriately (the possibility to isolate and compare the weights of grammatical cues occurs later, which coincides with Karmiloff-Smith's RR model). Prototypical constructions are characterized by an overlap of pragmatic, semantic, and syntactic attributes of the first noun (Bates, 1976; MacWhinney & Bates, 1989). To conclude, an interaction between syntax and semantics in the first stages of language acquisition was reported on the behavioral level. There is also confirming evidence from neuroimaging.

Contemporary neuroimaging studies in neurolinguistics reveal bilateral localization of semantic processes and a unilateral localization of syntactic processes in adults (Bozic, Tyler, Ives, Randall, & Marslen-Wilson, 2010; Wright, Stamatakis, & Tyler, 2012), whereas in children, syntactic processes are localized bilaterally (Skeide & Friederici, 2016). The latter authors demonstrated that "functional selectivity for sentence-level semantic information becomes neuro-anatomically separable from functional selectivity for sentence-level syntactical information between the ages of 7 and 9, and it is only after the age of 10 that BA44 (Brodmann's area) reaches its full specificity and ultimate efficiency in processing complex syntax" (p. 7).

The above-mentioned studies are aimed at general patterns of syntax development, but there are also studies of individual differences or distinct strategies in language acquisition. It is well known that this approach is one of the most productive for investigating mechanisms of language acquisition. Classical studies in ontolinguistics allowed researchers to distinguish two variants of language development: referential and expressive (Bates, Bretherton, & Snyder, 1988; Nelson, 1973; Shore, 1995; see also Dobrova, 2009). Modern researchers are continuing to analyze individual variability in mechanisms of the development and functioning of language comprehension through new neuroimaging methods in an event-related potential (ERP) paradigm (Pakulak & Neville, 2010; Prat & Just, 2011; Yeatman, Ben-Shachar, Glover, & Feldman, 2010). They discuss different factors such as working memory (Just & Carpenter, 1992, and subsequent works) or education level (Dąbrowska, 2012). However, to the best of our knowledge, no one has discussed distinct strategies of understanding GCs and their mechanisms.

Method

The aim of our study was to analyze the variability of mechanisms by which primary-school-age children understand reversible GCs, namely, to reveal individual differences in relying on word order or case endings, and to suggest possible interpretations of these mechanisms.

Participants and procedure

The children (93 first-graders, 93 second-graders, and 63 third-graders) underwent a neuropsychological assessment adapted for children (Akhutina et al., 2016), as well as a computer-based sentence-to-picture test of understanding reversible GCs: AD, AR, PD, and PR constructions. In this test, a child had to choose one of the two pictures, relevant to the heard sentence, by pressing a key (Akhutina, Korneev, & Matveeva, 2017a; Statnikov & Akhutina, 2013). Two indexes were used for further analysis: productivity (percent of correct answers) and time of correct responses.

Data processing

In order to divide the children into groups differing in their productivity of understanding the four types of GCs, k-means clustering was used (via SPSS, version 22). Relying on the results of preliminary hierarchical clustering (between-groups linkage), we decided to extract four clusters. They differed in all four variables used for the clustering (productivity of understanding AD, AR, PD, and PR constructions) (ANOVA, $p < .001$, see Table 2). The number of maximum iterations was 10.

Table 2

ANOVA in k-means clustering, demonstrating that four extracted clusters significantly differed in all four variables used for clustering.

	Cluster		Error		F	Sig.
	Mean square	df	Mean square	df		
AD	0.678	3	.021	245	32.994	.000
AR	0.587	3	.030	245	19.601	.000
PD	2.524	3	.021	245	123.063	.000
PR	2.609	3	.015	245	170.401	.000

Cluster 1 consisted of a small number of children with low productivity (6, 0, and 2 children from the first, second, and third grades, respectively); they were excluded from further analysis. Cluster 2 included children with low productivity in understanding PD structures (23, 18, and 12 children from the first, second, and third grades, respectively, hereinafter Group 1); Cluster 3 included children with poor understanding of PR structures (27, 22, and 13 children from the first, second, and third grades, hereinafter Group 2); Cluster 4 included the most successful children with a good understanding of all GCs (37, 53, and 36 children from the first, second and third grades, hereinafter Group 3). See Table 3 for final cluster centers.

Table 3

Final cluster centers

	Clusters			
	1	**2**	**3**	**4**
Productivity in AD	0.37	0.88	0.86	0.89
Productivity in AR	0.53	0.62	0.77	0.81
Productivity in PD	0.6	0.45	0.81	0.89
Productivity in PR	0.25	0.73	0.52	0.89

Neuropsychological indexes reflecting different components of higher mental functions were derived from the neuropsychological assessment. These indexes concerned (1) executive functions, (2) serial organization of movements, (3) processing of kinesthetic information, (4) auditory information, (5) visual information, and (6) visuospatial information. Furthermore, there were integral indexes of (7) left hemisphere and (8) right hemisphere functions, (9) functions of the first brain unit (regulation of activation level), as well as (10) a summary index of indexes 1–6. These indexes were calculated following the principle of "penalty points", with higher scores reflecting the "weakness" of the function, the sample mean equal to zero, and negative values reflecting the "strength" of the function. A more detailed description of the calculation of neuropsychological indexes can be found in Korneev and Akhutina (2016).

To examine the effects of group (1, 2, 3) and grade (1, 2, 3) on neuropsychological indexes, we carried out a two-way ANOVA (via R Studio). A distinct general linear model was calculated for each index (10 indexes in total), and p-values were Bonferroni-corrected for multiple comparisons.

Results

The distribution of children by Groups 1, 2, and 3 in the three grades was as follows: 26, 31, 43% (grade 1); 19, 24, 57% (grade 2); and 20, 21, 59% (grade 3).

Analysis of response productivity by groups (see Fig. 2 and Table 1A in Appendix) demonstrated that the percentage of correct responses for Group 1 was 84–95% in AD, 71–75% in PR, and 60–67% in AR. The percentage of correct responses in PD for this group was close to random (43–50%). The children in Group 2 were characterized by the greatest percentage of correct responses for AD (84–87%), lower percentages for PD and AR (77–91% and 75–80%, respectively), and a much lower percentage of correct responses for PR (47–57%). Finally, Group 3 showed high productivity in all GCs (79–91%). These data are in agreement with the hypothesis that Group 1 is under the influence of the rule "The first noun is the agent", whereas the other two groups rely on morphological aspects of the words in understanding GCs.

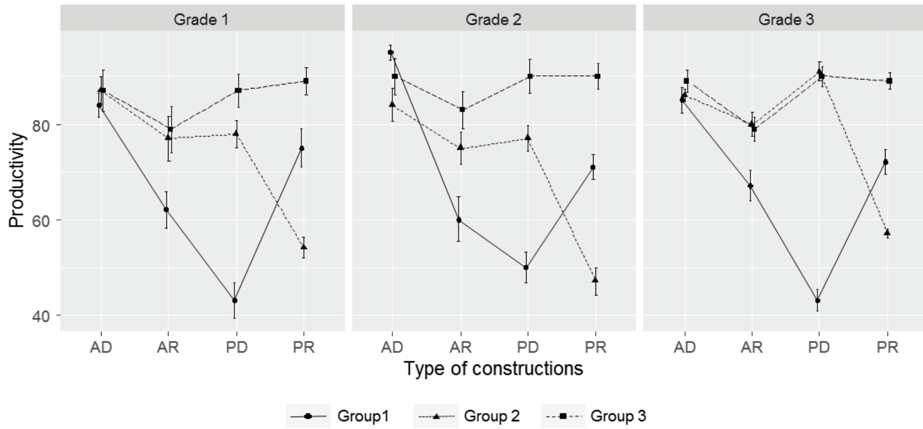

Figure 2. Productivity (means) for the three groups of children in grades 1–3.

Analysis of the time of correct responses by groups (see Fig. 3 and Table 1A in Appendix) showed that response time for AD was minimal for all groups in all grades. A minimal difference in response time between AD and the other GCs in the first grade was revealed between AD and PR in Group 1 (only 284 ms). This result supports the hypothesis that these children used the strategy of relying on word order in understanding passive constructions. However, in the second and third grades, response time for PR increased, although productivity in PR stayed the same. We will discuss these findings below.

The time of correct responses in AR was similar to AD. AR constructions were in the first place after AD in most cases for Groups 2 and 3; in Group 1 they took second place after PR in the first grade and first place in grades 2–3. An effortless understanding of AR constructions is an expected finding, because they are the next after AD in frequency of use and are linked to minimal changes in AD.

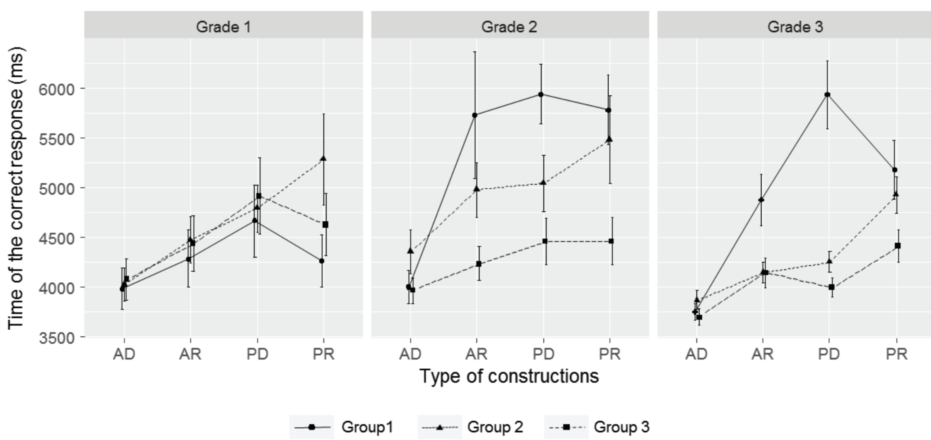

Figure 3. Time of the correct response (means) for the three groups of children in grades 1–3.

A maximal difference in response time between AD and the other GCs varied from one group to another. In all grades in Group 1, it was a difference between AD and PD; in Group 2, it was a difference between AD and PR. Group 3 differences in response times were slight, and the place of maximal difference varied from grade to grade.

Notably, Group 1 in the first grade was characterized by faster correct responses on average than the other two groups. However, the situation changed in the second and third grades: Group 3 became the fastest, while Groups 1 and 2 became much slower. This result is worth discussing too.

Table 4

Results of the two-way ANOVA, examining the difference between groups (1, 2, 3) and grades (1, 2, 3) in neuropsychological indexes. Bonferroni-corrected for multiple comparisons, and uncorrected p-values are given.

Neuropsychological index	**Group factor**	**Grade factor**	**Interaction between Group and Grade**
Executive functions (3.1)	$F(2, 219) = 5.54$, $p_{uncorr} = .004$, $p_{corr} = .04$*	$F(2, 219) = 5.43$, $p_{uncorr} = .005$, $p_{corr} = .05$*	$F(4, 219) = 1.19$, $p_{uncorr} = .32$
Serial organization (3.2)	$F(2, 221) = 7.9$, $p_{uncorr} = .9$	$F(2, 221) = 3.24$, $p_{uncorr} = .04$, $p_{corr} = .4$	$F(4, 221) = 0.77$, $p_{uncorr} = .54$
Processing of kinesthetic information (2.1)	$F(2, 221) = 0.09$, $p_{uncorr} = .002$, $p_{corr} = .02$*	$F(2, 221) = 6.27$, $p_{uncorr} = .002$, $p_{corr} = .02$*	$F(4, 221) = 0.25$, $p_{uncorr} = .9$
Processing of auditory information (2.2)	$F(2, 218) = 12.78$, $p_{uncorr} = .000006$, $p_{corr} = .00006$*	$F(2, 218) = 14.94$, $p_{uncorr} = .0000008$, $p_{corr} = .000008$*	$F(4 ,218) = 1.1$, $p_{uncorr} = .36$
Processing of visual information (2.3)	$F(2, 212) = 11.67$, $p_{uncorr} = .000015$, $p_{corr} = .00015$*	$F(2, 212) = 15.83$, $p_{uncorr} = .0000004$, $p_{corr} = .000004$*	$F(4, 212) = 2.24$, $p_{uncorr} = .07$
Processing of visuospatial information (2.4)	$F(2, 217) = 8.61$, $p_{uncorr} = .00025$, $p_{corr} = .0025$*	$F(2, 217) = 7.55$, $p_{uncorr} = .0007$, $p_{corr} = .007$*	$F(4, 217) = 0.23$, $p_{uncorr} = .92$
Left hemisphere	$F(2, 215) = 10.59$, $p_{uncorr} = .00004$, $p_{corr} = .0004$*	$F(2, 215) = 10.36$, $p_{uncorr} = .00005$, $p_{corr} = .0005$*	$F(4 ,215) = 0.3$, $p_{uncorr} = .87$
Right hemisphere	$F(2, 214) = 13.22$, $p_{uncorr} = .000004$, $p_{corr} = .00004$*	$F(2, 214) = 5.45$, $p_{uncorr} = .005$, $p_{corr} = .05$*	$F(4, 214) = 0.55$, $p_{uncorr} = .7$
Regulation of activation (the first brain unit)	$F(2 ,215) = 3.4$, $p_{uncorr} = .03$, $p_{corr} = 0.3$	$F(2, 215) = 8.87$, $p_{uncorr} = .0002$, $p_{corr} = .002$*	$F(4 ,215) = 0.6$, $p_{uncorr} = .66$
Summary index	$F(2, 200) = 18.2$, $p_{uncorr} = .00000005$, $p_{corr} = .0000005$*	$F(2, 200) = 27.67$, $p_{uncorr} = .00000000002$, $p_{corr} = .0000000002$*	$F(4, 200) = 0.93$, $p_{uncorr} = .44$

*Note: Results with $p \leq .05$, corrected for multiple comparisons, are marked with *.*

A two-way ANOVA examining the difference between groups (1, 2, 3) and grades (1, 2, 3) in neuropsychological indexes (see Table 4) led to the conclusion that 8 of 10 indexes (except processing of kinesthetic information and regulation of activation) significantly differed between groups; 9 of 10 indexes (except serial organization) differed between grades.

Analysis of the neuropsychological assessments demonstrated that Group 1 was "the weakest", whereas Group 3 was "the strongest" (see Fig. 4, and Table 2A in Appendix).

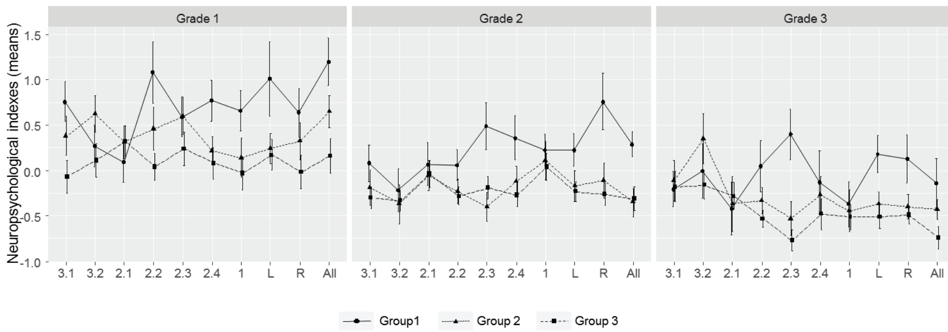

Figure 4. Neuropsychological indexes (means) for the three groups of children.

Note. 3.1 = executive functions, 3.2 = serial organization, 2.1 = processing of kinesthetic information, 2.2 = processing of auditory information, 2.3 = processing of visual information, 2.4 = processing of visuospatial information, L = left hemisphere index, R = right hemisphere index, 1 = the first brain unit index, All = summary index.

Spearman correlation coefficients between the four neuropsychological indexes of interest (processing of auditory and visuospatial information, as well as left and right hemisphere functions) and understanding of GCs were also calculated for each of the three groups (the distribution was not normal for some indexes). Significant correlations were found in Group 1 (AR and processing of visuospatial information [r_s = –0.29, p = .044], PD and processing of auditory information [r_s = –0.28, p = .048], PD and left hemisphere functions [r_s = –0.3, p = .04]) and Group 3 (AD and left hemisphere functions [r_s = –0.32, p < .0001], AR and left hemisphere functions [$r_{s\,=}$ –0.185, p = .045], PD and processing of visuospatial information [r_s = –0.23, p = .014], PD and left hemisphere functions [r_s = –0.27, p = .003], PR and right hemisphere functions [r_s = –0.2, p = .033]). Then, p-values were corrected for multiple comparisons (p < .05/4, i.e. p < .0125), and only two correlations for Group 3 remained significant: between AD and left hemisphere functions r_s = –0.32, p < .0001), and between PD and left hemisphere functions (r_s = –0.27, p = .003).

Discussion

Study of the understanding of active and passive GCs showed both common and different features in test performances of the three groups of children. All children were characterized by high productivity and the fastest correct responses to AD, being the prototypical constructions with the most frequent word order and morphological aspects. This finding may be explained through holistic recognition

(recognition by analogy) of AD constructions, which is accessible to children from the age of two (Dittmar et al., 2014).

The revealed differences allow us to suggest that children in Group 1 rely on the rule "The first noun is the agent". This is confirmed by the high productivity of their answers in AD and PR constructions, where the agent is in the first place. Evidence for this suggestion also includes the small percentage of correct responses (43, 50, 43% in grades 1–3, respectively) and the slowest response times (from 4,666 to 5,936 ms) in unfamiliar PD constructions. Responses to AR require additional explanations: they are slightly better than random (62, 60, and 67% in grades 1–3, respectively) but quite fast (4,288 ms, close to 4,264 ms for PR in the first grade). We hypothesize that AR constructions may also be recognized holistically, although to a lesser degree than AD.

Group 2 in all grades demonstrated minimal differences in response time between AD and AR constructions, and the maximal difference in productivity and response time between AD and PR constructions. These findings may be explained through, firstly, holistic recognition of AD and AR, and secondly, via a step-by-step acquisition of the rules of surface syntax. Rules of PR understanding are learned last; these constructions are rare and cannot be recognized as gestalts, and children cannot rely on word order in understanding them.

Children in Groups 1 and 2 are more rigid in using strategies; for understanding AR, PD, and PR constructions, they use distinct strategies. Children in Group 3 flexibly use different strategies.

It is most difficult to explain why Group 3 responds more slowly than the others in the first grade and much faster later, whereas Groups 1 and 2 demonstrate a significant increase in response times from the first to the third grade. Children of Group 3 have the best neuropsychological scores and are most successful at school. Acquisition of reading and writing skills has been found to improve the structural-functional organization of language and perception (Dehaene, Cohen, Morais, & Kolinsky, 2015). These authors hypothesized that such a reconstruction may also influence syntactic processes. If they are right, it may explain the earlier reorganization and temporal imbalance of language processes in the most successful children (in first grade), which takes place later in less successful children (in second and third grades). This hypothesis requires further examination.

How may our data be combined with the above-mentioned facts regarding the development of GC understanding in children aged 3–5 years? The obtained results demonstrate that the strategy of reliance on word order is persistent in a significant part of 7- to 9-year-old children, which is an unexpected finding due to the data of 1985–1989 (Akhutina, 1989; Akhutina, Velichkovskiy, & Kempe, 1988; Kempe, 1985). Can our results be explained using Karmiloff-Smith's RR model? This model allows for a coexistence of multiple representations of a singular knowledge: There are multiple levels at which the same knowledge is represented. For instance, specialists in aphasiology are very well familiar with the possibility of actualizing procedurally represented knowledge in patients' involuntary utterances (Jackson, 1884; Luria, 1970). Akhutina (1989) explains two other facts in the speech of patients with agrammatism, by the stability of procedural knowledge. Firstly, she points to the frequent usage of correct (but not regular) GC constructions, which are sometimes rejected by patients in accordance with the new knowledge reflected by them

("*Mal'chik myls'a – net! – myt's'a k mal'chik. Mama myl v mal'chik*" / "The boy washed himself – no! – to wash to the boy. The mother washed in the boy"). Secondly, she notes the best performance on tests of grammaticality judgment compared to tests of the construction and understanding of GCs. This is interpreted through reliance on auditory-motor stereotypes that represent, in accordance with the ideas of N.A. Bernstein (1967), "a background technical level in the surface-syntactical design of an utterance" (Akhutina, 1989, p. 167). This can be considered as a procedural level in the RR model. Modern researchers of children's speech have described the discrepancy between understanding and constructing GCs, on the one hand, and syntactic priming tests, on the other, which also may be explained through representations of different levels (Huttenlocher, Vasilyeva, & Shimpi, 2004).

Regarding the persistence of the rule "The first noun is the agent", we suggest that in children it may coexist with the rules of GC understanding of different levels: a procedural one (as in the case of high-frequency constructions, AD, and to a lesser degree AR), and one that is more mature, close to an adult level (taking both inflections and word order into account, as in passive constructions). Different levels of representations may win in the competition for the rules in different children (compare to the Competition Model in MacWhinney & Bates, 1989).

The stability of the word order rule we found may be linked to the agent advantage in event recognition: If the Agent is in the first place, that facilitates the interpretation of events (Cohn, Paczynski, & Kutas, 2017; Hafri, Trueswell, & Strickland, 2018). The retention of events in long-term memory might possibly also be associated with the Agent advantage, and this might explain the widespread overgeneralization of the word order rule in children between 3.5 and 4 years old, when access to episodic memory becomes available.

Finally, the last comment addresses the localization of syntactic processes. In our previous publications regarding children in the first and second grades (Akhutina et al., 2017a and 2017b), we wrote about the increasing role of the left hemisphere and involvement of both hemispheres in the strategy "The first noun is the agent". In our current work, we found that understanding AD and PD constructions correlates with the functioning of the left hemisphere in Group 3, the most successful group. These correlations remained significant after correction for multiple comparisons. Significant correlations in Group 1 were found between AR understanding and the index of visuospatial perception, as well as between PD understanding and the index of left hemisphere functions and auditory information processing; however, these correlations become nonsignificant after correction for multiple comparisons. We interpret these facts as a manifestation of the more diffuse nature of syntactic processes' representation in Group 1, as well as an increasing role of the left hemisphere in children of Group 3 being more successful in syntactic processes, which is consistent with the literature (Pakulak, & Neville, 2010; Skeide & Friederici, 2016).

Conclusion

1. Primary-school-age children demonstrate different strategies of GC understanding, relying either on word order ("The first noun is the agent"), or on the complex usage of both inflections and word order.

2. Group 1 is the weakest in neuropsychological indexes and Group 3 is the strongest. The children of these groups differ in more or less diffuse activation of the brain: Group 3 demonstrates predominantly left-lateralized activation, whereas Group 1 is characterized by more diffuse activation.
3. We suggest the following possible interpretation of the fact that Group 3 is the slowest at first, becoming the fastest later, whereas the other two groups, conversely, become slower in the second grade: this may be linked to a restructuring of language mechanisms caused by acquiring literacy. Successful children of Group 3 acquire reading skills earlier, so this restructuring occurs earlier in them and later in the other two groups.

Limitations

We analyzed the results of independent samples in the first, second, and third grades, and therefore this study was not longitudinal. A longitudinal study must be carried out for more precise results.

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Appendix

Table 1A

Productivity and time of correct responses (means) for the three groups of children.

Grammatical construction type	Grade	Productivity (% correct responses)			Time of correct responses (ms)		
		Group 1	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
AD	1	84	87	87	3,980	4,025	4,079
	2	95	84	90	4,002	4,358	3,967
	3	85	86	89	3,757	3,872	3,700
AR	1	62	77	79	4,288	4,476	4,441
	2	60	75	83	5,728	4,977	4,233
	3	67	80	79	4,880	4,149	4,144
PD	1	**43**	78	87	4,665	4,792	4,915
	2	**50**	77	90	5,936	5,046	4,458
	3	**43**	91	90	5,934	4,251	3,998
PR	1	75	**54**	89	4,264	5,283	4,628
	2	71	**47**	90	5,782	5,482	4,459
	3	72	**57**	89	5,180	4,925	4,414

Table 2A

Neuropsychological indexes (means) for the three groups of children

Neuropsychological index	Grade	Group 1	Group 2	Group 3
Executive functions (3.1)	1	0.76	0.38	–0.07
	2	0.08	–0.19	–0.3
	3	–0.21	–0.11	–0.18
Serial organization (3.2)	1	0.27	0.62	0.11
	2	–0.22	–0.37	–0.33
	3	–0.005	0.35	–0.16
Processing of kinesthetic information (2.1)	1	0.09	0.31	0.32
	2	0.07	–0.06	–0.04
	3	–0.42	–0.37	–0.28
Processing of auditory information (2.2)	1	1.08	0.46	0.04
	2	0.06	–0.23	–0.28
	3	0.05	–0.33	–0.53
Processing of visual information (2.3)	1	0.59	0.6	0.24
	2	0.49	–0.4	–0.19
	3	0.4	–0.53	–0.77
Processing of visuospatial information (2.4)	1	0.77	0.22	0.08
	2	0.36	–0.12	–0.27
	3	–0.13	–0.27	–0.48
Left hemisphere	1	1.01	0.24	0.17
	2	0.23	–0.17	–0.23
	3	0.18	–0.37	–0.51
Right hemisphere	1	0.64	0.32	–0.02
	2	0.76	–0.11	–0.26
	3	0.13	–0.4	–0.49
Regulation of activation (the first brain unit)	1	0.66	0.14	–0.03
	2	0.23	0.11	0.04
	3	–0.37	–0.45	–0.51
Summary index	1	1.2	0.65	0.16
	2	0.29	–0.35	–0.31
	3	–0.14	–0.43	–0.74

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Developing Secondary Language Identity in the Context of Professional Communication

Galina V. Denissova[a*], Ekaterina A. Redkina[b], Anna A. Zalizniak[c]

[a] *Department of Philology, Literature and Linguistics, Pisa State University, Pisa, Italy*

[b] *Department of Psychology, Lomonosov Moscow State University, Moscow, Russia*

[c] *Russian Academy of Sciences, Russia*

* Corresponding author: E-mail: galina.denissova@unipi.it

Background. Studying the concept of secondary language identity is one of the main problems in educational psychology since it involves the ability to use a foreign language effectively in various fields. Since languages don't exist in a vacuum but are culture-bound, a person's process of psychological transformation into having a secondary language identity entails profound psycholinguistic and psycho-sociological character changes. However, professional communication differs significantly from everyday cross-cultural communication, which means that it should be studied separately.

Objective. The aim of this paper is to propose a theoretical approach to the development of secondary language identity within professional communication.

Design. Particular interest is paid to how language is taught, and which teaching methods and techniques will ensure the development of secondary language identity in the professional context. In this article we propose that the method of foreign language teaching is one of the factors underlying the development of secondary language identity in a professional context.

Results. As professional communication is always culture-specific and culture-dependent, culture influences language teaching in two ways: linguistically and pedagogically. Linguistically, it affects the semantic, pragmatic, and discourse levels of language. Pedagogically, it influences the choice of language materials.

Conclusion. We apply the methodology of Content and Language Integrated Learning (CLIL) and the use of the translation method to analyzing the development of secondary language identity in a professional context.

Keywords:
secondary language identity, professional communication, cultural differences, cross-cultural communication, language/culture teaching, multi-competence, content and language integrated learning, translation method.

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Introduction

The main purpose of foreign language teaching can be understood as psychologically transforming a student into having the so-called "secondary culture identity," described as the process of accumulation of a set of abilities (competences) which prepare a person for foreign language communication in a multi-cultural field (Karaulov, 1987; Khaleeva, 1989; Gal'skova, 2000; Nechaev, 2014). Since language has no independent existence, foreign language teaching is culture teaching, and someone involved in learning a new language is simultaneously involved in learning a new culture.

Cross-cultural professional communication assumes that all sorts of ambiguous communicative situations occur in content-specific contexts, and therefore require developing language consciousness, particularly in professional communication. Although the development of a secondary language identity in professional communication on the surface looks different from the development of a general secondary language identity, its successful formation depends on solving the most important methodological problems, which primarily include the following:

1. understanding the process of intercultural communication as a form of joint activity realized through sharing basic categories and concepts;
2. forming internal mechanisms of awareness of tasks, conditions, and adequate means and methods of communicative activity in the context of a particular "subject matter-oriented" activity (Nechaev, 2014). The theoretical basis for such awareness lies in linguistics and linguadidactics, and the psychology of speech.

The most relevant cognitive and psychological problems involved in foreign language acquirement are well described by the phenomenon of "culture shock." This includes the learner's feelings of estrangement, loneliness, and even physical illness (Brown, 1996, p. 35), and the instantaneous "culture bump" that occurs (whether individuals are aware of it or not) "when an individual has expectations of a particular behavior within a particular situation and encounters a different behavior when interacting with an individual from another culture" (Archer, 1996, p. 171). By expectations we mean the expectations of normal behavior as learned in one's own culture. Several ramifications emerge from encountering a culture bump. These include an emotional response, a knowledge dichotomy which results in a search for information, and the formation of a perception.

The relationship between language and culture has been debated by philosophers, linguists, and social scientists alike. Philosophy has been addressing this question at least since the Ancient Greek debate between those who thought that the relationship was natural and those who considered it to be subjective and conventional. In the Middle Ages, realists claimed that words denoted concepts that corresponded to actual entities, whereas nominalists maintained that concepts only signified names or words.

The mutual relationship between language and culture, i.e. the interaction of language and culture, has long been a issue, thanks to the writings of prominent philosophers such as W. von Humboldt (1876), L. Wittgenstein (1980), T. Adorno (1993), or M. Foucault (1994); linguists such as F. de Saussure (1966), N. Chomsky (1968), or A. Wierzbicka (1997); and psychologists such as L.S. Vygotsky (1983), A.R. Luria (1976), or P.Ya. Galperin (1997). These are the names that first come to mind when addressing the problem of the relationship between language and culture.

Yet, the most distinguished linguists dealing with this relationship are E. Sapir (1921) and B.L. Whorf (1952). They are the scholars whose names are often used synonymously with the term "Linguistic Relativity." The core of their theory is that a) we perceive the world in terms of categories and distinctions found in our native language; and b) what is found in one language may not be found in another language due to cultural differences.

Contrary to Chomsky's theory about an innate biological basis for language (Chomsky, 1968) and the ideas of S. Pinker (Pinker, 1994) concerning language instinct, language use is social. Thus, the idea of a biological language instinct seems to be controversial in the field of linguistics: "Although there is no doubt that anything may be said in any language, the relationship between language and culture makes it easier to say certain things in some languages than in others" (Kaplan, 1996, p. 18).

The concept of the "linguistic worldview" (Humboldt's "Weltanschauung") refers to the cognitive function of language. The human being has the ability to communicate with other people by means of a system of conventional signs, which refer to classes of phenomena in extra-linguistic reality. Hence, a certain cognitive view of the world, its categorization, and the conceptualization of the perceived phenomena are encoded in the human mind. People who identify themselves as members of a certain social group acquire common ways of viewing the world through their interactions with other members of the same group. Common attitudes, beliefs, and values are reflected in the way members of the group use language, i.e. what they choose to say or not to say and how they say it. The view of the world which is established in language, is not identical to encyclopedic knowledge of the world. Languages differ among each other in this respect.

In an approach that appeals to anthropologists, psychologists, and philosophers as well as linguists, A. Wierzbicka (1997) demonstrated that every language has "key concepts" (or "inscriptions in memory"), expressed in "key words" which reflect the core values of a given culture but often have no parallel in other languages. The fact that language is culture-bound, ensures profound psycholinguistic and psycho-sociological changes during a person's psychological transformation into having a secondary language/culture identity. In a certain sense, a foreign language class seems to be the best laboratory to study how the linguistic mind works.

Teaching professional content and the skills of professional communication through a foreign language first of all requires a thorough understanding of professional cross-cultural phenomena. Secondly, it involves the application of a teaching methodology that can help students reflect on the differences between professional concepts as expressed in their L1 (native language) and in L2 (foreign language); compare and critically analyze the linguistic component; raise awareness of their own cultures; and use various skills effectively in cross-cultural professional communication, both oral and written. One such approach is Content and Language Integrated Learning (CLIL), a dual-focused approach used for teaching both content and language. Unlike other educational practices, such as bilingual education, immersion, EAL (English as an additional language), and others, CLIL provides a more holistic educational experience at different levels: communicative, cognitive, content, and cultural. The latter plays a particularly important role in the modern globalized world (Dalton-Puffer et al., 2010).

The dialectical connection between language and culture that determines our "inscriptions in memory" has always been a concern of foreign language (L2) educators. Whether the culture of the target language is to be incorporated into L2 teaching has been a subject of rapid change throughout the history of language teaching. For example, during the first decades of the 20th century, researchers discussed the importance and possibility of including cultural components into the L2 curriculum (Sysoyev & Donelson, 2002). Then the advent of Communicative Language Teaching (CLT) in the late 1970s marked a critical shift for teaching culture, with the paradigm shift from an approach based largely on form and structure, to a plurality of approaches causing the unintended side effect of neglecting the issue of culture (Pulverness, 2003).

Recent studies, such as those by scholars Byram (1989, 1994), Kramsch (1993, 2001), and Ter-Minasova (2000), have focused on the seamless relationship between L2 teaching and target culture teaching, especially over the last decade. The emphasis in 20th century pedagogy was on the external goal of "behaving" in the L2 environment, rather than the internal goal of achieving better cultural attitudes or greater cognitive flexibility. Nevertheless, in many educational systems, communication is only one among many overt or covert goals, and often a subsidiary or far-distant one. Although by the mid-1980s, various advantages of teaching culture in L2 classes were virtually universally accepted, and culture was widely taught in language classes, there were still problems about what should be taught, and how culture could be taught most beneficially.

Another question that has become most acute in the contemporary world, is the interconnectedness of culture and professionalism. It is impossible to achieve professional success without cultural awareness and intercultural understanding (Jarotskaya, 2016). "If we follow the idea that culture determines the way we interpret the world, and that we use language to express this interpretation, then CLIL opens an intercultural door, where learners can have experiences which they could not have had in a monolingual setting–meaning, for example, that it provides a rich catalyst for 'living' intercultural experiences which are fundamental to a deeper understanding of global citizenship" (Coyle, Hood, & Marsh, 2010, p. 138).

The problem is that most L2 students around the world live in a monolingual environment and consequently, they become monocultural individuals. The main task of foreign language/culture teaching therefore is the advancement of a students' ability to consciously overcome their native concepts. Language teaching means, among other things, making people think differently. In other words, it helps students to view cultural differences not as problems to be solved but as opportunities to learn more about themselves and others. "Culture associated with a language cannot be `learned' in a few lessons about celebrations, folk songs, or costumes of the area in which the language is spoken. Cultural awareness may focus on knowledge about different cultures, but the move towards intercultural understanding involves different experiences" (Coyle, Hood, & Marsh, 2010, p. 139).

In professional communication, the reading of content-specific texts–which is the most common teaching method–seems limited and insufficient for overcoming possible problems in cross-cultural professional communication. As for grammar books, there is still this misconception adopted both by language teachers and students, that a deep grasp of a new language's grammar will inevitably and most naturally lead to successful professional cross-cultural communication. However, in reality, learning grammar does not contribute much to the cross-cultural communicative competence which lies at the core of successful communication, both every-day and professional.

The starting point here is the concept of multi-competence, i.e. the knowledge of two or more languages in one mind. This term was devised to encompass both language systems present in the same mind, the first language and the interlanguage (Selinker, 1972). While "interlanguage" has become the standard term for the speaker's knowledge of a second language, no word existed that encompassed his or her knowledge of *both* the second language (L1) *and* the first. Hence "multi-competence" was introduced to mean "knowledge of two or more languages in one mind" (Cook, 1991, p. 115), as seen in *Figure 1*.

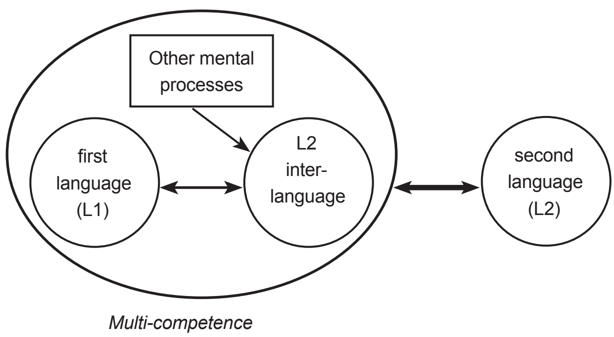

Figure 1. Model of Multi-competence (Cook, 1991)

This graphic reflects the idealized relationship between the two languages in the same mind. At one end of the continuum the two languages are quite distinct; at the other end they are completely merged; in-between come different ways in which the two languages can be linked together. Since the first language/native culture and the other language(s)/culture(s) are in the same mind, they must form a language super-system at some level rather than completely isolated systems. "Intercultural dialogue involves using skills to mediate between one's own and other cultures" (Coyle, Hood, & Marsh, 2010, p. 141).

The cognitive sciences have provided us with simple but very useful ideas about meaningful learning, i.e. a positive approach to learning that comes from the relationship between previous knowledge (native language/culture) and new knowledge (foreign language/culture). The following four possibilities represent different points on the integrative continuum for relating the two languages in the L2 user's mind (Cook, 2003, pp. 1–18), applied to the domain of concepts:

1. *L2 concepts are not acquired.* The L2 user acquires the language, but not the conceptual system, and effectively uses L1 concepts with the L2.
2. *The two sets of concepts exist in separate compartments.* The L2 user effecttively thought-switches between the two concept-systems when appropriate.

3. *The two sets of concepts are integrated to some extent.* The L2 user has partially over-lapping concept-systems.
4. *A new conceptual system has been created.* The L2 user thinks neither in the same way as a native speaker of the first language, nor in that of a native speaker of the second language, but in a distinctive way that differs from both. This is exactly what a secondary language/culture identity is.

Let us turn to some consequences of this for language teaching in the professional context. Learning another language means changing the contents of one's mind. Language teachers are engaged, among other things, in the task of affecting the whole minds of the students. The multi-competence idea and the changes in cognition affect not only the goals but also the techniques of language teaching. In this context we support the use of the CLIL 4Cs Framework, which includes content, communication, cognition, and culture. As a communicative approach, the CLIL teaching methodology suggests minimizing the use of L1 in the classroom. However, in what follows, we shall propose a framework for empirical research on the question why the translation method should be used in foreign language classes, and generate working hypotheses which are potentially useful for the development of a secondary language identity in professional communication.

Methods

Translation has more than one purpose. Its main aim is to serve the cross-cultural bilingual communication vehicle among people of different cultural backgrounds. That is why the problems of teaching cross-cultural professional communication and translation training are in many ways inseparable. This methodology, as opposed to the traditional practice of training for cross-cultural communication, allows students to use a foreign language effectively for the purposes of professional content-specific communication, and supports the evolution of bilingualism in the most natural way.

Translation activity, founded on the general principle of "frequency and recency of activation" (Luria, 1976; Paradis, 1993), establishes a bilingual network in the student's brain that connects each L2 unit directly with the equivalent unit of the L1, and reduces the frequent occurrence of those linguistic and cultural pseudo-equivalents that are actually the main source of communication failures.

Results

Training for cross-cultural bilingual professional communication by means of translation may minimally be defined as the union of several rather important skills:

1.*Comprehension and interpretation ability* implies the application of this approach to various types of texts, considering various aspects and levels: text, reference, cohesion, and "naturalness." This competence includes reading, comprehension, and message interpretation (encoding and decoding). Translating is a discourse operation interposed between language and thought, so the skill of translating helps to develop the ability to overcome numerous obstacles.

The first obstacle is related to reading and comprehension ability in the source language. Once the translator has coped with this obstacle, the most frequent translation difficulties are of a semantic and cultural nature. This includes such problems as "linguistic untranslatability" (cognates, i.e. calque and other forms of interference; institutional and standardized terms, neologisms, aphorisms, etc.) or cultural "untranslatability" (idioms, sayings, proverbs, jokes, puns, etc.); being able to manage losses and gains; and finding solutions to lexical ambiguity, etc., through mechanisms such as compensation, loans, explanatory notes, adaptation, equivalence, paraphrasing, analogies, etc.

One should adopt a very cautious attitude towards these words or expressions so as to avoid interference and/or language misuse. One of the greatest virtues of training in a foreign language and translation at the same time is the development of the so-called "contextualized intuition," i.e. the ability to find the nearest common sense interpretation of the "not found" element within its context, and being able to assess earnings and losses and show self-correction ability.

2. The *re-wording skill* means applying various strategies for the restitution of the message (recoding) by choosing the appropriate method(s), techniques, and procedures. The most frequently used procedures for the restoration of ideas contained in a translation unit call for the student to use transfer, cultural or functional equivalence, synonymy, transposition, modulation, compensation, reduction, and expansion or amplification. For this purpose, it is also indispensable for the student to make effective use of different types of documentation: parallel texts, monolingual and bilingual dictionaries, encyclopedias, term data base, informants, and other sources.

3. *The ability to make constant choices*, in each paragraph, sentence or translation unit, so as to decide which of them is most useful for transferring the ideas in the text being translated. Cognition, in the form of self-consciousness and self-confidence, plays a very important role in the preparatory phase of a translation, in as much as this period implies conscious mental activities where translating problems are detected and analyzed, and information and knowledge are accumulated.

4. *The capacity to generate a TT (target text) series of more than one viable term (TT1, TT2...) for a ST (source text).* This skill can also help to replace a binary approach to language learning (only right and wrong) with a non-binary one which presupposes at least two right answers, as well as wrong ones.

5. *The ability to select only one TT*, quickly and with justified confidence, and to propose this TT as a replacement for the ST for a specified purpose and reader. It is a process of generation and selection between alternative texts that should be taught, and presumably what is usually not taught in a language class (Pym, 1992).

Discussion

Since translation remains under the tutelage of foreign language learning, this area of knowledge could be described as "linguistics applied to translation." This discipline aims to shape the following profile of L2 students: sound linguistic training in two languages; knowledge covering a wide cultural spectrum; high reading comprehension competence; adequate management of documentary sources; capacity for analysis and self-criticism; efficient data processing training at the user's level;

and writing their own language well. Last but not least: training for cross-cultural communication by means of translation essentially interweaves the culture bump, as both a concept and as a strategy, into an intercultural communication workshop, with each step taking the student from culture bump, to culture-specific information, to an underlying universality. In sum, this approach is intended to develop the student's secondary language identity with professional language consciousness in the most profitable way.

Conclusion

Language teaching means making people think differently. Seeing, being aware of, and understanding these differences in professional communication result from applying certain methodological and teaching approaches. In order to view cultural differences not as problems to be solved but as opportunities to learn more about oneself and others, we need to turn to the problem of the formation of secondary language identity in the professional context. Understanding the role of cultural professional content in the development of secondary language identity is the crucial factor contributing to successful cross-cultural professional communication.

As for teaching approaches, communicative CLIL methodology and the translation method can be effectively combined. The CLIL approach works at a micro level of meaningful interaction between peers in the classroom, and at a macro level outside the classroom in cross- and intercultural communication. Translation is not referred to as the classical translation method, but rather as so-called "translation competence" based on cross-linguistic analysis that helps in clarifying "key concepts"/"key words" and removing linguistic and cultural pseudo-equivalents, the main source of miscommunication. Such a methodology makes it possible to most effectively use a foreign language for the purposes of practical professional communication, and provides for the evolution of bilingualism in the most natural way.

Limitations

Currently, the proposal to improve translation competence in the system of intercultural communication training based on cross-linguistic analysis, is supported only at the empirical level, and remains open not only to modifications, but to radical changes as well. In this context, the identification and analysis of the role of translation in foreign language teaching requires a strong conceptual framework before it can ensure any heuristic validity.

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Information-processing in French Adults Practicing Deception

Gabriella Fekete*

Laboratoire Dynamique du Langage, Université de Lyon, France

*Corresponding author. E-mail: fekegab@gmail.com

Background. Experiences which people have and perceive personally (Skowronski et al., 1991) are interpreted in a subjective way (Weiss & Cropanzano, 1996) and stored in autobiographical memory along with information related to their lifetime periods, general events, and event-specific knowledge (Conway & Pleydell-Pearce, 2000; Larsen & Thompson, 1995). These three specific knowledge-types are intertwined and come up together when an individual is recalling memories (Conway, 1996).

Objective. The aim of our study is to investigate how French adults process information in deceptive speech. We observed the information-types used in the three knowledge-types of autobiographical memory in monologs and answers to questions.

Method. Our data comes from videotaped spontaneous oral speeches produced by 17 French adults. The participants were given the task of producing a fake opinion paradigm on their favorite sport.

Result. Our results show discrepancies in the frequency of the three knowledge-types of autobiographical memory used in the true and deceptive speech of practitioners and viewers. We also found that certain information-types are linguistic-context-dependent while others are systemic. The findings highlight the fact that some information is missing and/or replaced, and other information is nuanced in deception compared to truthful speech.

Conclusion. This study can contribute to a better understanding of deceivers' cognitive processing, as well as demonstrating the close relationship between language and cognition.

Keywords: deception, information-processing, knowledge-types of autobiographical memory, monolog, questioning

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Introduction

Deception is "a successful or unsuccessful deliberate attempt, without forewarning, to create in another a belief which the communicator considers to be untrue" (Vrij, 2008, p. 15). It is a cognitively taxing task (Adams-Quackenbush, 2015; Karim et al., 2010; Vrij, 2000; Zuckerman, DePaulo, & Rosenthal, 1981) that requires numerous cognitive processes activated non-linearly. They include: recall of past events; coherent elaboration of invented events; linguistic encoding; cognitive inhibition; and attention (Adams-Quackenbush, 2015; Buller & Burgoon, 1996).

Research on lying has been expanding over the past decade. Studies of the verbal and nonverbal characteristics of deceptive speech have been widely investigated in the United States and the United Kingdom, and their main findings have been tested in many languages. Researchers have been interested in different verbal indicators, such as pronouns, semantic verb types, adjectives, syntactic structures, perceptual, emotional and spatial-temporal information, inter-clausal connectors, and negations (Arciuli, Villard, & Mallard, 2009; Bond & Lee 2005; Connelly et al., 2006; Hancock, Curry, Goorha, & Woodworth, 2005, 2008; Johnson & Raye, 1998; Newman, Pennebaker, Berry, & Richards, 2003; Pennebaker, Mehl, & Niederhoffer, 2003; Peucheret, 2014).

Verbal and nonverbal cues exclusively indicating deception do not exist (Sporer & Schwandt, 2007; Vrij, 2005), and the cross-linguistic results are not homogeneous. This might be explained by several factors:

1. Analyzing separately linguistic units like pronouns as indicators of psychological distancing (Bond & Lee 2005; DePaulo et al., 2003; Hauch, Blandón-Gitlin, Masip, & Sporer, 2012; Mehrabian, 1971; Newman et al., 2003) leads to the loss of information carried by the linguistic context which can express the opposite (*I took the money* vs. *I received the money by mail*);
2. Cross-linguistic comparisons should take into account the different linguistic properties of the target languages; thus, generalization from findings based on the English language, such as the frequency of different semantic verb-types (action verbs vs. stative verbs), must be treated with caution (for the typology of encoding systems of motion events, see Talmy, 1985);
3. Different-corpus-based results are not always comparable: for example, spontaneous or prepared oral narratives (Mihalcea & Strapparava, 2009) or interactions (Hancock et al., 2005); interview dialogues (Levitan, Maredia, & Hirschberg, 2018); written narratives (DeCicco & Schafer, 2015); or computer-mediated written interactions like emails and sms (Dou, Liu, Muneer, & Schlussel, 2017; Zhou, Burgoon, & Twitchell, 2003)

In the present paper, we consider deceptive speech as a whole, and observe it from a macrostructural perspective. Deceptive speech generally contains 95% truth, but the deceiver prepares his 5% untruth from the beginning of his/her speech. Consequently, this mental preparation affects all his/her cognitive processes, and thus the structuring of his/her entire story, including the true parts.

We tend to investigate how lying speakers verbally build up experiences and reasoning, taking into consideration linguistic- and extra-linguistic-contextual factors. It is very important to capture the different types of information the deceiver uses to keep psychological distance regarding events. The cognitive processes that are reflected in his/her language use could let us get closer to the deceiver's way of thinking.

First, we discuss previous findings on the storage of lived experiences in the memory and the macro-structural markers used in deceitful speech. After presenting our assumptions and describing the methodology used to collect and process the spoken data, we will describe all the alternative information-types found in the three knowledge-types of autobiographical memory in the French adults' speeches. Note that our aim is not to propose a new method for detecting deception. We are interested in how the deceivers process information.

Personal experiences in memory

Events are lived and interpreted in a subjective way according to both individual and contextual factors (Weiss & Cropanzano, 1996) and stimulate the affective system (Forgas, 1999). Both personally-lived (*self-events*) and -perceived experiences (*other-events*) (Skowronski, Betz, Thompson, & Shannon, 1991) are encoded and stored in autobiographical memory (Larsen & Thompson, 1995). The encoded information does not uniquely consist of the event itself, but is associated with other related information such as the context and the individual's affective state (Geiselman, Fischer, Cohen, Holland, & Surtes, 1986). Autobiographical memory stores three specific knowledge-types: those related to lifetime periods = (1a); general events = (1b); and event-specific knowledge = (1c) (Conway & Pleydell-Pearce, 2000). For example:

When I was young (1a), we had a big garden (1b); I often played on a swing there (1c) and I was always afraid of falling down (1c).

These knowledge-types are inter-connected and emerge together when an individual is recalling specific autobiographical memories (Conway, 1996).

Event-specific knowledge, including sensory-perceptual experiences, plays a key role in distinguishing perceived events from imagined events (Conway, Collins, Gathercole, & Anderson, 1996). According to Johnson and Raye (1981), perceived experience should be stored with more perceptual and contextual information and meaningful details in the memory; conversely, an imagined event should contain more information about cognitive operations.

Deceptive discourse is essentially generated by cognitive operations and comprises unlived experiences; therefore, it is generally composed in a vague and less detailed way (Johnson & Raye, 1998; Porter & Yuille, 1996; Vrij, 2000). It is less coherent and syntactically less complex (Newman et al., 2003; Porter & Yuille, 1996). It contains more pauses, word repetitions, and speech disturbances (DePaulo et al., 2003; Mann, Vrij, & Bull, 2002; Vrij, 2008). The reaction time of deceivers is longer (Farrow et al., 2003; Walczyk, Roper, Seemann, & Humphrey, 2003). "Untrue speech" is generally less plausible, with more words expressing negative emotion (Newman et al., 2003). There is no consensus on production length (Granhag & Stromwall, 2002; Hancock et al., 2008; Sapir, 1996).

Li and Santos (2011, 2012) have addressed the issue of deception cues from another perspective. They tried to retrieve the reasoning process of deceivers using natural language-processing techniques applied to the data. Truth-tellers' and deceivers' reasoning may show discrepancies because their basic belief systems are not similar. Their results suggest that the deceptive reasoning is built up from arguments based on presuppositions. These arguments are closely related to each other, and serve the deceiver's purpose.

In the present paper, we try to investigate the deceiver's expression of experiences and reasoning in order to capture discrepancies in his/her way of thinking. We will analyze deceptive speech in four types of situation: 1) spontaneous monologs; 2) answers to questions requiring feelings; 3) the reasoning processes of truth-tellers and deceivers who affirm having lived experiences; and 4) of those who pretend to have had perceived experiences.

Research questions

The aim of our study is to observe the reflection sequences of truth-tellers and deceivers in order to detect discrepancies in their belief systems regarding events presented in deceptive speech, as compared to true speech.

Previous findings suggest that the three knowledge-types (lifetime periods, general events, and event-specific knowledge) of autobiographical memory are inter-connected (Conway, 1996), and event-specific knowledge is a main characteristic of really lived and perceived experience (Conway et al., 1996). This latter experience-type is stored with more perceptual and contextual details in the memory (Johnson & Raye, 1981). In deception, the three knowledge-types are not stored and cannot be recalled. Consequently, deceptive speech is mainly based on cognitive operations (Johnson & Raye, 1981) and presuppositions (Li & Santos, 2011, 2012) with fewer perceptual and contextual details (Johnson & Raye, 1981, 1998; Porter & Yuille, 1996; Vrij, 2000) and more negative affect (Newman et al., 2003).

Based on the results of these studies we hypothesized that:

- The synchronic presence of the three knowledge-types of autobiographical memory, but primarily event-specific knowledge, should appear infrequently in a deceptive reflection sequence.
- Individuals who truly lived an experience should express more specific details on events related to themselves. Individuals who truly perceived an experience should describe more context-detailed information. However, individuals who falsely affirm personally experienced events should give more general, cognitively-deduced information.
- Lifetime-period-knowledge should be primarily mentioned in the case of past experience in monologs or answers to questions oriented to this information-type. Continuous and/or repetitive experience does not require this knowledge-type.
- Event-specific knowledge is stored with personal feelings which are missing in unlived experience. Consequently, more affective information should occur in deception to compensate for this lack. Note that affective information is a subjective evaluation-type referring to a specific event. However, a general situation also can be evaluated. This latter is separated from the former with nuanced linguistic tools. So, a situational evaluation can hide the untrue nature of information which can be merged with affective evaluation. Consequently, this evaluation-type should appear more often in deception.

Method

Speakers

Videotaped data were collected from 17 monolingual native French speakers, twelve women and five men. The mean age was 28.07 years (19.03-55.09). The speakers were selected based on their willingness to perform the task. There was no qualification as to sex or education. They knew neither the aim of the study nor what they would be asked to do.

Task

The task used to obtain the texts was a fake opinion paradigm on a favorite sport. This method has already provided the basis for several previous studies (Newman et al., 2003; Mihalcea & Strapparava, 2009). The participants were asked to relate truthful and deceptive positive opinions about sports that they like and dislike. Sports were chosen as the main topic because all study participants were sports-persons.

We needed a comparable "norm", namely the linguistic dynamics of truthful speech, in order to investigate the deceptive speech. Consequently, the task consisted of two parts: a discussion about the participant's favorite sport (the "true part"), and then another discussion about the participant's least favorite sport, which was introduced as his/her favorite one (the "deceptive part"). We began the task with the true monologs for two main reasons: on the one hand, to allow the participants to feel at ease with a familiar topic (Burgoon & Qin, 2006), and on the other hand, to increase their cognitive load with unexpected questions (Tekin et al., 2015) and then a deception request thereafter. The monologs were followed by questions in both parts.

It is important to emphasize that the aim of the study was to get the participants to talk, so that we could observe the linguistic and cognitive characteristics of their deceptive speech. Deception detection was not an objective of the present study.

A comparison of the two discourse-types (monologs and answers) can reveal interesting discrepancies because individuals telling the "untruth" do not organize the flow of information in the same way as when they are telling the truth. Thus, deceivers possess "freedom of expression" without any particular orientation in monolog. It follows that they can arbitrarily decide which information and details to tell. Thus, they expect to draw attention to the true parts of their story. However, questioning imposes on them a specific orientation with cognitive constraints which deprives them of their "expressive freedom".

Depending on their answers to the question *Do you practice this activity?*, the participants were classified as either practitioners or viewers.

Protocol

The discussion had been conducted by the author. The same protocol was used for all participants. They were interviewed individually in an isolated room at their workplace. The office walls were uniformly painted white, with neither pictures nor patterns on the walls. The interviewer and the participant sat face to face without anything between them. The participant was placed with his/her back to the window and/or the door. This allowed us to avoid any cognitive bias.

The introduction of the task consisted of several steps.

First, the researcher started a discussion in order to defuse tension and get the participant to forget the camcorder. Then she asked him/her to talk about his favorite sport. Once the participant had finished his/her monolog, the investigator asked questions such as: *What do you like about this activity? How often do you do it in a week? With whom do you practice? Do you compete? Can you quote me some game rules?*

After the questioning, the researcher asked the participant to stand up, take a walk around the chair, and again to be seated, in order to get him/her out of the truth-telling, corporal, and cognitive dynamics. Then the investigator requested him/her to talk about the sport he/she likes least, but as if it were his/her favorite sport. The interviewer never mentioned the word "lie" because the direct request to "sell" a story causes participants to outperform. The subsequent questioning of the participant about his/her deception was comprised of questions similar to those asked about the truth.

Transcription and coding

The recorded productions were transcribed, segmented into clauses, coded, and analyzed by the author. A clause is a unit that contains a predicate (an inflected [2a] or non-inflected [2b] verb, or a predicative adjective [2c]). The predicate should describe a situation (activity, event, state) (Berman & Slobin, 1986). Examples of the coding follow:

(2) a. Donc aujourd'hui, je *fais* plus mon sport préféré. 1 clause
'So nowadays, I do not *do* my favorite sport anymore.'
(Quentin, Truth, 00:38-40)

b. Je viens de partir en Autriche. / *Skier*. 2 clauses
'I just went to Austria. / *Skiing*.'
(Dorian, Truth, 00:53-56)

c. Et puis en général, l'ambiance autour d'un match *est* plutôt *intéressante* aussi. 1 clause
'And then in general, the ambience around a match *is* rather *interesting* too.'
(Jeanne, Deception, 4:09-13)

This minimal unit was adopted because oral speech often comprises a succession of clauses (rather than sentences) whose start and end are difficult to determine.

One-way and two-way analysis of variance measuring deception, "expressive freedom", and experience-type effects have been calculated for checking on the effect-relatedness of results. The quantified data represent the mean percentages.

Information-types

We identified ten information-types within the whole body of data.

We labeled lived experiences (3a) as all factual information related to personal practice, and perceived experiences (3b) as practice's follow-up, such as watching tv. For example:

(3) a. *J'en ai fait* pendant 10 ans à Bron jusqu'en Championnat de France.
'*I had done* for 10 years in Bron until France Championship.'
(Kahina, Truth, 00:39-44)

b. Quand *tu vois* un match de rugby.
'When *you are watching* a rugby match.'
(Arthur, Deception, 03:09-03:10)

Contextual information (4) described all general information not directly related to the personal experience but to the environment in which the experience took place.

(4) Donc il y a pas besoin de… 50,000 accessoires.
'So, there is no need for… 50,000 accessories.'
(Nadège, Truth, 01:06-10)

We distinguished feeling and affect. We considered as personal feeling (5a) an event-specific sensation provoked by lived and perceived experience. However, affect (5b) is part of an event-general evaluation. A general-situational evaluation (5c) is coded as evaluation.

(5) a. J'évacue... toutes les mauvaises ondes.
'I evacuate all the bad vibes.'
(Adeline, Truth, 00:31-00:34)

b. J'aime bien ce sport.
'I like this sport.'
(Clémentine, Deception, 02:56-57)

c. Et c'est vraiment génial avec les compétitions et tout. / C'est super.
'And it is really great with competitions and all. / It is super.'
(Gaëlle, Deception, 02:57-03:00)

We also identified aptitude information (6) such as body control, endurance, rigor, and team spirit which describe the physical and mental skills developed through practice. This information-type can be related either to general-event knowledge in a truthful speech, or to a supposition deduced from general cognitive knowledge in deception.

(6) Il faut beaucoup de concentration. / Etre très méticuleux.
'It requires a lot of concentration. / One should be very meticulous.'
(Laetitia, Deception, 03:50-03:54)

Bodily information (7) refers to the corporal properties of individuals or the corporal effects of practice.

(7) Bah physiquement ça muscle vraiment harmonieusement le corps, le dos.
'Well physically, it strengthens really harmoniously the body, the back.'
(Jeanne, Deception, 03:40-03:44)

The last information-type is technical information (8). We consider it as event-specific knowledge related to sport-type.

(8) Vu que c'est le ballon. / Qui est en l'air. / C'est quand-même... aérodynamique.
'Because this is the ball. / That is in the air. / It is anyway aerodynamic.'
(Alizée, Truth, 01:16-01:19)

Results

Information-types in Monologs

Figure 1 displays the different information-types found in the monologs of the French speakers who affirmed a lived experience.

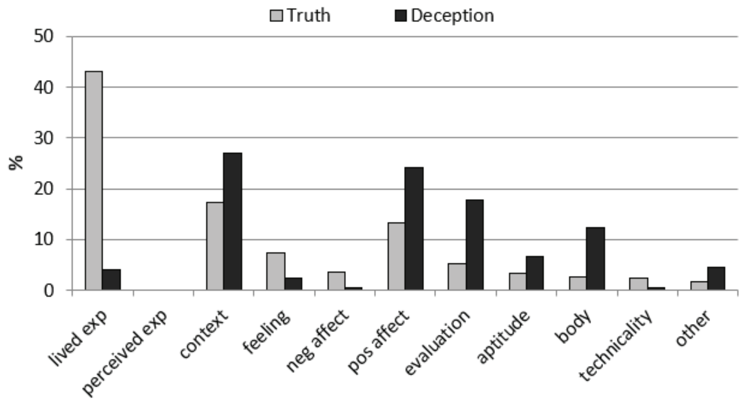

Figure 1. Information-types in monologs of French speakers practicing their favorite sport.

Figure 1 reveals that personal facts about lived experience are spontaneously mentioned more in true discourse ($F(1,23) = 14.85$, $p = .0008$) than in deception. Both general-situational evaluation and bodily information score significantly higher in deceptive speech ($F(1,23) = 16.61$, $p < .02$ and $F(1,23) = 5.68$, $p < .03$, respectively). Other speech characteristics appear with similar frequency in both truthful and deceptive monologs.

Figure 2 shows the different information-types found in the monologs of the French speakers who affirmed perceived experience.

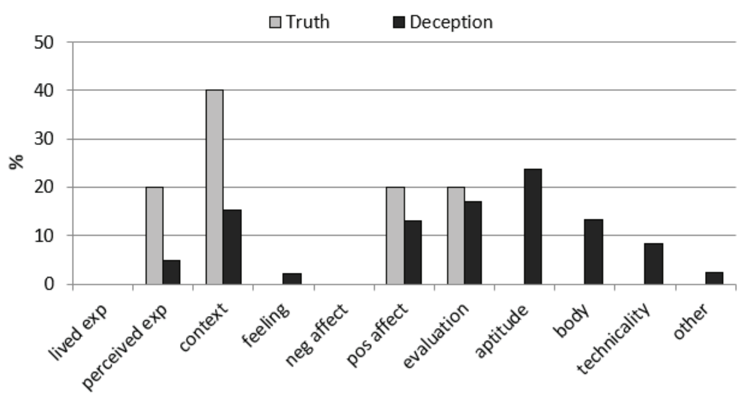

Figure 2. Information-types in monologs of French speakers viewing their favorite sport.

Although one-way analysis of variance shows no deception-related effect, truth-tellers who perceptually experience specific events talk about their perceived experience and environmental context more often than deceivers do. It is notable that aptitude-, body- and technicality-information are mentioned only in deceivers' monologs about supposed perceived-experience. The frequency of positive affect and evaluation is similar in truth and in deception.

In sum, true monologs contain significantly more lived experiences ($F(1,27) = 16.88$, $p = .0003$) than deceptive discourse. Perceived experiences do not show discrepancies according to deception-effect ($F(1,27) = 0.004$, $p = \text{NS}$). Therefore, they appear significantly more often in viewers ($F(1,27) = 33.94$, $p < .0001$) than in practitioners. Two-way analysis reveals an interaction between deception and perceived-experience effects ($F(1,25) = 93.46$, $p < .0001$). This means that viewers telling the truth give information about perceived experience significantly more often than practitioners or deceptive viewers do in their monologs. No difference is found in the frequency of contextual information, feeling, and negative and positive affect. Evaluative information is impacted by deception-effect ($F(1,27) = 6.86$, $p < .02$) but not the experience-type effect ($F(1,27) = 1.18$, $p = \text{NS}$) in the French monologs of our data. There is no interaction between the two factors.

Deception has no effect on aptitude information ($F(1,27) = 2.42$, $p = \text{NS}$). Therefore, one-way analysis of variance with experience-type effect shows that there is generally a tendency for viewers to give aptitude-information ($F(1,27) = 3.72$, $p < .07$). The global deception effect on body-information is significant ($F(1,27) = 7.58$, $p < .02$) in the monologs. Thus, deceivers–practitioners as well as viewers–tend to evoke physical aspects more often than truth-tellers do. Technicality occurs with similar frequency in both truthful and deceptive discourse.

Information-types in Answers

In order to obtain comparable data, we investigated the answers to Wh-questions that involve the speaker and require event-specific feeling-information with some reasoning. We chose reactions to the questions: *What do you like about this sport? What does this activity bring to you physically and mentally?*

Figure 3 illustrates the information-types produced by the French speakers as supposed practitioners during questioning.

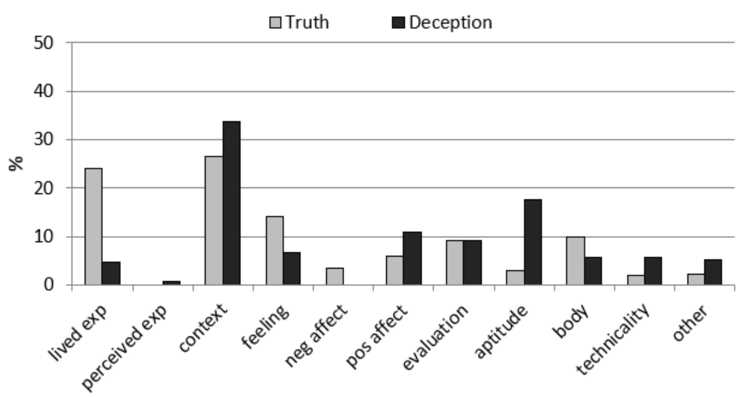

Figure 3. Information-types used in answers by French speakers practicing their favorite sport.

Real practitioners tend to mention lived experience more often ($F(1,14) = 4.37$, $p < .06$) than false practitioners do. One-way analysis of variance with deception effect shows no significant effect for all the other aspects.

Figure 4 displays the information-types which occur in the French viewers' answers.

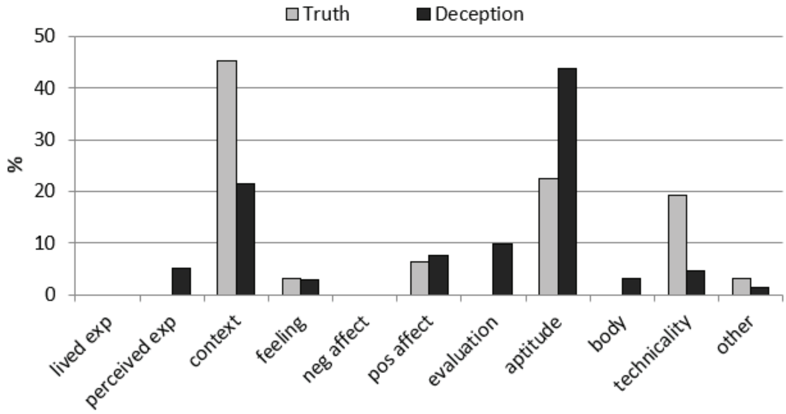

Figure 4. Information-types used in answers by French speakers viewing their favorite sport.

There is a preference for contextual information in true answers. Its frequency increases in truth-tellers and decreases in deceivers, compared to practitioners. Only untrue viewers evaluate general situation during questioning. Deceivers favor aptitude-information which shows up more often in both truthful and deceptive viewers than in practitioners. Technical information is primarily expressed in true speech. One-way analysis of variance with deception-effect shows no significance for all the information-types.

In sum, true answers to feeling-oriented questions generally contain significantly more lived experiences ($F(1,19) = 5.22$, $p < .04$) than do false answers, irrespective of experience-type. The French speakers of our data similarly mention aptitude in both true and deceptive answers, but this information-type is significantly more frequent in viewers ($F(1,19) = 5.5$, $p = .03$) than in practitioners.

Information-types in Monologs and Answers

Generally speaking, certain information-types are linguistic-context-dependent while others are systemic.

Lived experience scores significantly higher in true ($F(1,48) = 25.22$, $p < .0001$) than in deceptive speech. It has a tendency to be produced more in monologs ($F(1,48) = 3.86$, $p < .06$) than during questioning. Lived experience is only present in practitioners' data of our corpus, and it is significantly related to this experience-type ($F(1,48) = 5.12$, $p < .03$). No interaction is observed between the three factors (deception, expressive freedom, and practice). Neither deception ($F(1,48) = 0.34$, $p =$ NS) nor expressive-freedom effects ($F(1,48) = 0.01$, $p =$ NS) are significant for perceived experience. Therefore, this information-type appears significantly more often in viewers ($F(1,48) = 19.65$, $p < .0001$) than in practitioners.

Our French speakers give contextual information and talk about their feelings in a similar way in truth and deception, monologs and answers, and lived and perceived experiences. Negative affect is expressed significantly more often in true monologs and answers ($F(1,48) = 5.94$, $p < .02$). Neither deception nor experience-type effects have an impact on positive affect ($F(1,48) = 1.1$, $p = \text{NS}$ and $F(1,48) = 0.46$, $p = \text{NS}$, respectively), which is rather influenced by expressive freedom. It is significantly more frequent in monologs ($F(1,48) = 4.72$, $p < .04$).

Evaluative information tends to be used more in deception ($F(1,48) = 3.97$, $p < .06$) than in truth. Aptitude scores significantly higher in deceptive ($F(1,48) = 7$, $p < .02$) than in truthful speech; in answers ($F(1,48) = 4.8$, $p < .04$) rather than in monologs; and in viewers ($F(1,48) = 11.14$, $p < .002$) rather than in practitioners. The three factors act independently. The French practitioners and viewers in our study talk about physical properties and effects, and give technical information similarly in truthful and deceptive speech, and monologs and answers.

Autobiographical Knowledge-types in Monologs

In order to study different autobiographical knowledge-types, we separated individuals who currently practice a given sport from those who have stopped the activity.

We considered context-, aptitude- and body-information as general-event knowledge, and lived and perceived experiences, feeling- and technicality-information as specific-event knowledge. Given that affect is an evaluation-type, we classified it with general-situational evaluation.

Figure 5 shows autobiographical knowledge-types expressed in the monologs of the French current-practitioners.

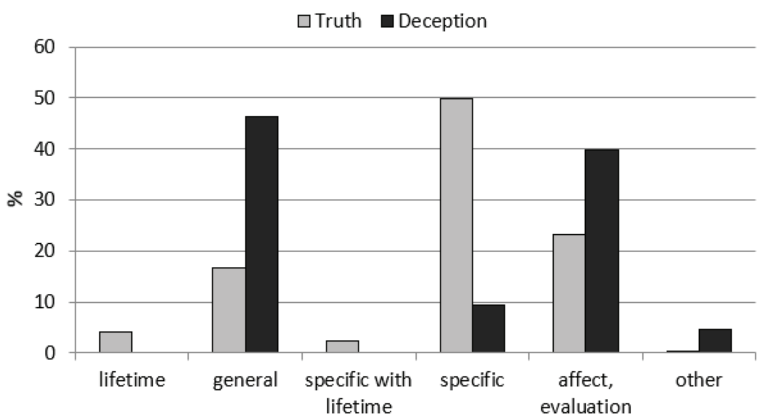

Figure 5. Autobiographical knowledge-types in the monologs of French current-practitioners.

Figure 5 reflects the fact that lifetime period, general- and specific-event knowledges are synchronically present when French truth-tellers talk about their current activity in monologs. They rarely mention the lifetime period in a single clause or integrated within a specific-event (9).

(9) Depuis toute petite, je monte à cheval.
'Since childhood, I ride.'
(Clémentine, Truth, 00:35 - 00:37)

It is important to note that reference to a lifetime period is only found in true speech in our current-activity data. One-way regression analysis signals a truth-tendency for both this knowledge-type ($F(1,21) = 3.43$, $p < .08$) and its integration into a specific event ($F(1,21) = 4.12$, $p < .06$). General-event knowledge occurs significantly more often in deception ($F(1,21) = 13.52$, $p < .002$) than in a truthful monolog. Specific-event knowledge is significantly more frequent in true discourse ($F(1,21) = 30.15$, $p < .0001$) than in deceptive monolog.

Figure 6 shows the autobiographical knowledge-types which appear in the monologs of French past-practitioners.

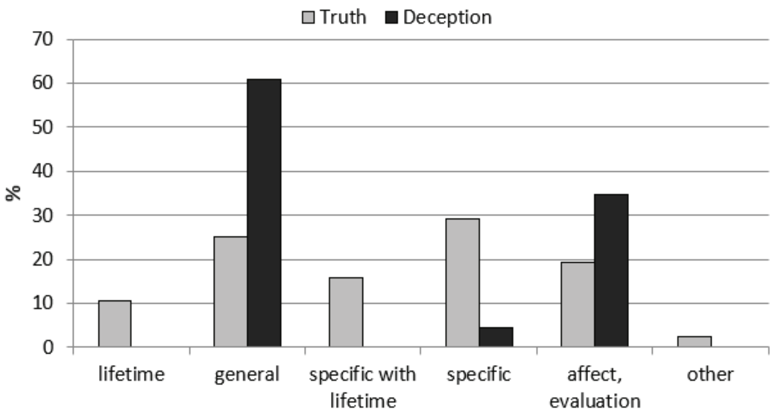

Figure 6. Autobiographical knowledge-types in the monologs of French past-practitioners.

The synchronic presence and frequency of the three knowledge-types in the past-practitioners' monologs demonstrate the same tendency as those in current-practitioners. The lifetime period only occurs in true discourse in a single clause or integrated within a specific-event, and it occurs more often for past-activity than for current-activity. General-event scores higher in deceivers' monologs ($F(1,10) = 2.03$, $p = \text{NS}$), and specific-event is more frequent in truth-tellers' discourse ($F(1,10) = 1.37$, $p = \text{NS}$), but these differences are not significant. As in current-activity, the expression of both affect and evaluation is more frequent in deception. One-way analysis of variance found no deception-effect on all the speech characteristics.

As for autobiographical knowledge-types viewed generally, the mention of lifetime events in a single clause and specific events connected with lifetime-periods only occur in truth-tellers. A lifetime period cited in a single clause is true- ($F(1,33) = 5.71$, $p < .03$) and past-related ($F(1,33) = 5.71$, $p < .02$). A lifetime period embedded within a specific event is not impacted by the truth-effect ($F(1,33) = 2.33$, $p = \text{NS}$); therefore, it occurs significantly more often in past-practitioners' monologs ($F(1,33) = 5.38$, $p < .03$). General-event scores significantly higher in deceptive speech ($F(1,33) = 13.34$, $p = .0009$) than in true monologs in both current- and past-activities ($F(1,33) = 0.21$, $p = \text{NS}$). French truth-tellers talk about specific-events significantly more often in monologs ($F(1,33) = 19.34$, $p = .0001$) than French deceivers do, in both current- and past-activities ($F(1,33) = 0.31$, $p = \text{NS}$). Affective and evaluative expressions are significantly more frequent in deception $F(1,33) = 5.35$, $p < .03$), and have a tendency to occur most often in current-activities ($F(1,33) = 3.73$, $p < .07$).

Discussion

Our main results show discrepancies in true and deceptive speech. French speakers refer more often to a lifetime period when recalling personally lived past events. This finding supports our hypothesis on the past-related significance of lifetime period knowledge. Thus, ongoing activities are actually related to the present; therefore, they do not need to be specified. Only truth-tellers talk about this knowledge-type, and mainly in a single separated clause, and recall more specific-events for both current- and past-activities than deceivers do.

These results confirm our hypothesis which expected that the frequency of synchronic presence of the three knowledge-types should be lower in deceptive discourse, and specific-event knowledge higher in truthful speech. This is an individual-related factor. Deceivers who did not personally live the experience did not systematically store information in memory. To fill this lack, they give more general event-information and do more evaluation of events and situations. These two information-types will be discussed in more detail later.

Generally speaking, certain information-types are related to linguistic context, while others seem to be systemic.

Lived experience occurs more often in truthful than in deceptive speech, more in monologs than answers, and more in practitioners than in viewers. Perceived experience is expressed more often in viewers than in practitioners. Thus, lived events are always interpreted and stored from an individual point of view (Forgas, 1999; Skowronski et al., 1991; Weiss & Cropanzano, 1996) based on the individual's own sensory and corporal experiences due to *embodiment* (Barsalou, 2008 ; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005).

Negative affect characterizes truthful speech while positive affect is related to the expressive freedom of monologs. These findings do not confirm our hypotheses and previous research on the higher score for negative and positive affect in deception (DePaulo et al., 2003; Newman et al., 2003). The more frequent negative affect in true discourse could be due to the fact that truth-tellers do not hesitate to express deprecation of some event-aspects. Deprecation is natural. However, deceivers could believe that expressing negative affect could betray their false discourse.

Evaluative information tends to occur more in deception, in accord with our hypothesis. Evaluation is part of cognitive appraisal, including reasoning. Deceivers want not only to convince their interlocutor about the truthfulness of their story, but also to close the topic with an evaluative conclusion. *We are on a tatami. It is cool.* (Jérémy, Deception). Interrogators rarely request reasoning after such an evaluation (*Why is it cool?*).

Aptitude is more frequent in deception, appears more in answers, and viewers express it more than practitioners. We suggest that aptitude is a deduction via general cognitive knowledge, and that it is an alternative to reasoning (if necessary) because it is feeling-like. Take the interchange: Q: *What do you like in this activity? A. That one must be rigorous.* The interrogator considers rigor a positive affect by association, which is an erroneous cognitive process. Can we like an activity for the aptitude it requires? Particular activities require aptitudes for better performance, but it is not necessary for practice. However, certain activities provoke intimate sensations and feelings that emerge only during their practice. Consequently, we propose that deceivers justify appreciation either with feelings transferred from a real experienced activity, or with an aptitude, if they already had a perceived experience with the activity.

Our French speakers (especially the truth-tellers) with perceived experience obviously expose these experiences in their monologs. They also give more aptitude-information than speakers with lived experience. Monologs by real practitioners contain more lived experiences. Deceivers, in contrast, evaluate general situations and discuss corporal aspects more often than truth-tellers do in their monologs. During feeling-oriented questioning, true answers contain more lived experiences, and viewers talk about aptitude more often than practitioners do.

Contextual-, feeling- and technical-information seem to be systemic with no discrepancy based on deception, expressive-freedom, and experience-type effects, according to our results. These results can be explained by the fact that neither context nor technicalities require experience. Each individual can know them through his general knowledge. As for feeling, it is not often expressed; it is part of the intimate sphere that individuals may not like to expose.

Table 1 summarizes information-types with their different effects found in the data produced by our French participants.

Table 1

Impact of different effects on information types found in French monologs and answers

	Deception	**Expressive freedom**	**Experience-type**
Lifetime-period knowledge (truth- and past-related)			
General-event knowledge (deception-related)			
Context	-	-	-
Aptitude	deception	answer	viewer
Body	in deceptive monolog	-	-
Specific-event knowledge (truth-related)			
Lived experience	truth	monolog	practitioner
Perceived experience	-	-	viewer
Feeling	-	-	-
Technicality	-	-	-
Evaluation (deception- and current-related)			
Negative affect	truth	-	-
Positive affect	-	monolog	-
General evaluation	deception	-	-

Conclusion

Our aim in this paper was to observe how French speakers manage information-processing in deceptive monologs and answers when recounting personally lived or perceived experiences. Our data are composed of spontaneous spoken speeches produced by 17 French adults.

The results reveal important aspects of the speakers' way of thinking in deception, which is multi-faceted and extremely sensitive to linguistic and extra-linguistic context. Events lived or perceived personally generate specific details stored in memory that French deceivers do not provide in spontaneous oral speech. In addition, they use both linguistic and cognitive subtleties to counter an interlocutor's suspicion. Thus, some information is missing and/or replaced, and other information is nuanced in their deceptive speech.

A multidisciplinary approach provides relevant support for tracking the characteristics of deceptive language and cognition because there is a bidirectional interaction between them. Deceivers' reflection sequences are reflected in the linguistic tools they use. On the other hand, their language modulates their perception of the world (Berman & Slobin, 1994; Whorf, 1956). Consequently, future studies should take into account the specific features of both the target language and culture.

Limitations

Although our results provide relevant points and a guideline for future research on information-processing in deception, we have identified some limitations.

First, our separation of lived and perceived experience-data was based on the speakers' answers to the question *Do you practice this activity?*. The majority affirmed they were practitioners in both the truth and deception tasks. Consequently, the sample size of the two experience-types was not well-balanced, which can explain the lack of significant results for perceived experience.

Second, some results, like positive and negative affect, could have been impacted by the fact that the experimental task-type was emotionally charged. Deceivers were asked to talk about their least favorite sport as if it were their most favorite one. This request can be interpreted as excluding negative affect and highlighting the positive one.

Finally, we did not separate affirmation and argumentation in our analysis. Indeed, there is a huge difference between *The weekend is the moment for matches* (Alizée, Truth) and *I like running because it is free* (Julie, Deception). Consequently, this generalized treatment can hide the visibility of the effect-significance of certain information-types such as context, feeling, and technicality.

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A Four-Dimensional Spherical Model of Interaction Between Color and Emotional Semantics

Andrey A. Kiselnikov[a*], Arkadii A. Sergeev[b], Dmitriy A. Vinitskiy[a]

[a] *Lomonosov Moscow State University, Moscow, Russia*

[b] *Psychological Institute of Russian Academy of Education, Moscow, Russia*

*Corresponding author. E-mail: kiselnikov@mail.ru

Background. The color and emotional systems are classical research objects in psychology and cognitive neuroscience, but the interrelations between them, especially at the semantic level, are poorly understood. The multidimensional approach, developed in E.N. Sokolov's "vector psychophysiology" school of thought, permits the solution of this important problem.

Objective. To carry out a psychophysical study of the interaction between color and emotions at the semantic level, through the analysis of subjective multidimensional spaces.

Design. The stimuli were the Russian names of 10 basic colors and 10 basic emotions. 102 participants used a scale from 1 to 9 to evaluate subjective differences in all possible combinations of color–color, emotion–emotion, and color–emotion. A 10×10 color submatrix, 10×10 emotion submatrix, and 20×20 full color–emotion matrix were processed by multidimensional scaling.

Results. The subjective spaces extracted from the color and emotion submatrices were found to be four-dimensional and spherical. The model of color semantics features two chromatic ("Red-Green" and "Blue-Yellow") and two achromatic ("Semantic Brightness" and "Contrast Grey") opponent axes. The model of emotional semantics features two basic ("Valence" and "Arousal") and two social ("Dominance" and "Social Rejection") opponent axes. The integral color-emotional space also was found to be four-dimensional and spherical, featuring combined color-emotional axes.

Conclusion. The interaction between color and emotional semantics can be described with a four-dimensional spherical model, proving that E.N. Sokolov's universal spherical model can adequately describe the processes of intermodal integration at the semantic level.

Keywords:
color, emotion, semantics, multidimensional scaling, spherical model, affective circumplex, vector psychophysiology

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Introduction

Two important domains of the human mind, emotion and color, have taken different evolutionary paths but can interact in their development, both phylogenetic and ontogenetic. Emotions can be regarded as a universal mechanism of integral assessment of the effect that the internal and external environment has on the realization of subject's needs (Simonov, 1997). The emotions acquire the function of a global low-differentiation assessment (Mehrabian & Russell, 1974), by contrast with a high-differentiation cognitive assessment. Trichromatic vision (Hiramatsu, Melin, Allen, Dubuc, & Higham, 2017), which formed in primates as a component of an evolving system of high-differentiation local cognitive assessment of the environment, is incorporated into the low-differentiation system of global emotional assessment of their mammal predecessors. A verbal system forms in the process of anthropogenesis and genesis of culture, so that color and emotions as individual mental domains, along with their interaction (the incorporation of colors into emotional assessment) have their effect on the verbal level, leading to the formation of color and emotion semantics and a system of color–emotion semantic associations. The functioning of such a system is an important problem of psychology and cognitive neuroscience. In our study, we were inspired by the multidimensional approach to cognitive neuroscience (E.N. Sokolov's "vector psychophysiology" school of thought, based on a universal spherical neuroinformational model).

Few studies have focused directly on color–emotion interaction. Hemphill (1996) used direct verbal associations and showed that the brightness scale is related to the hedonistic emotional scale. Zentner's (2001) work on the ontogenesis of color–emotion associations confirmed the relationship between emotional pleasure and brightness. Sutton and Altarriba (2016) showed associations between negative emotions and the colors red and black, and Hupka, Zaleski, Otto, Reidl, and Tarabrina (1997) showed similar associations in a cross-cultural study. Terwogt and Hoeksma (1995) used real colors and facial expressions of emotion and found that color–emotion preferences in adults showed no significant correlation with those in children.

Ou, Luo, Woodcock, and Wright (2004a, 2004b) used scaling of real colors in 10 "color–emotion" scales, corresponding to Osgood's three factors. A three-dimensional model was constructed: color activity, color weight, and color heat. They used a small sample to examine not separate color stimuli, but all their possible pair combinations, and factor analysis identified the same three factors. Gilbert, Fridlund, and Lucchina (2016) used a design in which the participants were to directly assign a color to each emotional term. They showed that emotions are significantly differentiated by all three color characteristics.

Of greatest interest for our study are the works of A. Mehrabian. First, in cooperation with J. Russell, he developed a three-dimensional model of emotions, Pleasure–Arousal–Dominance (PAD) (Mehrabian, 1996; Mehrabian & Russell, 1974; Russell & Mehrabian, 1977); second, he described the emotional characteristics of the real colors specified in the Munsell system by these three scales (Valdez & Mehrabian, 1994). Brightness was found to contribute most to the dimension of Pleasure, saturation to the dimension of Arousal, and brightness inversely contributes to the dimension of Dominance. Weaker regularities were found for hue. In the study of brightness and saturation, the differences between the stimuli under the PAD model are much greater than those in the study of hue. So, this study systematically examined the interaction of Munsell's characteristics (hue, value, and chroma) and emotions (PAD); however, a limitation of this approach was the lack of a full scheme of factor-to-factor interaction and the use of a predetermined system of emotional scales.

None of these studies considered multidimensional models of color and emotions in their potential interaction (except for that of Valdez and Mehrabian [1994], which, however, had the limitations described above). In our view, the method that can be used to solve this problem is Sokolov's vector psychophysiology approach (Sokolov, 2013). This is based on the construction of multidimensional models of mental processes with the use of multidimensional scaling of large above-threshold differences and their subsequent integration with multidimensional neurophysiological models. Vector psychophysiology uses a universal spherical neurocybernetic model of cognitive, affective, and motor processes (including elementary two-channel spherical modules of coding brightness, color, size, orientation, etc.). The biological background of Sokolov's model is formed by his analysis of information processes in real neuron networks in the brains of animals and humans and the development of an isomorphic model of cognitive architecture.

Sokolov's spherical model was empirically proved with the use of psychophysical and neurophysiological methods for color and emotions at both the perceptual and semantic levels (color perception: Izmailov & Sokolov, 1991; Sokolov, 2000; color semantic: Izmailov & Sokolov, 1992; emotion perception: Sokolov & Boucsein, 2000; Boucsein, Schaefer, Sokolov, Schröder, & Furedy, 2001; Izmailov, Korshunova, & Sokolov, 2005; emotion semantic: Izmailov, Korshunova, & Sokolov, 2008). However, with this approach, no model of interaction between color and emotions was constructed based on earlier separate models of color and emotions. In our view, such a formulation of the problem, implying the construction of a model of interaction between color and emotions and based on separate models of color and emotions, will not have the drawbacks of the previous studies that used other experimental paradigms (e.g., Valdez & Mehrabian, 1994).

We propose a new method for constructing a model of the interaction between color and emotions, based on unifying the subjective scales of color–color, emotion–emotion, and color–emotion differences. First, we propose to use the basic names of colors and emotions, rather than real colors and facial expressions. This is because Sokolov's vector psychophysiology studies showed that the subjective space of the names of basic colors is four-dimensional and spherical and essentially isomorphic to the subjective space of real basic colors, and the subjective space of the names of basic emotions is also four-dimensional and spherical and also essentially isomorphic to the subjective space of real facial expressions (Sokolov, 2013). Therefore, the difference between semantic stimuli will correspond to the difference between the same stimuli represented as real colors or as facial expressions. Second, the transformation of stimulation into a unified semantic format allows the participant to more easily compare the colors and emotions with one another (i.e., to compare words with words, rather than real colors with facial expressions). Third, based on the above reasoning, we propose a uniform scale of subjective differences, whereby the participant, in the subjective scaling of differences in pairs of words denoting color–color, emotion–emotion, or color–emotion, uses the same uniform scale (e.g., 1 to 9), rather than three different scales. This uniform scale can potentially actualize the implicit color–emotion relationships, thus enabling their measurement and analysis. We have successfully tested this approach in pilot experiments (Kiselnikov et al., 2016a, 2016b).

Methods

Stimuli. The stimuli were the Russian names of the 10 basic emotions (the set of six basic emotions according to P. Ekman (Ekman, 1999): *happiness, surprise, fear, sadness, disgust, and anger,* expanded according to Izard's classification (Izard, 1991) with the words *calmness, shame, contempt, interest*) and 10 basic colors (seven spectral chromatic colors: *red, orange, yellow, green, sky-blue, blue,* and *violet*, and three achromatic colors: *white, grey*, and *black*) (Russian original stimuli for emotions: *радость, удивление, страх, печаль, отвращение, гнев, спокойствие, стыд, презрение, интерес*; for colors: *красный, оранжевый, жёлтый, зелёный, голубой, синий, фиолетовый, белый, серый, чёрный*). Altogether, there were 20 stimuli (the names of 10 emotions and 10 colors).

Experimental procedure. Each stimulus was presented as a slide against a black background with a resolution of 1366 by 768 pixels on a 15.6″ laptop screen, using specially developed software, VectScal "Multidimensional Scaling of Visual Stimuli". The text of each slide was written in the monospaced Lucida Console font. In the experimental procedure, the participant had to assess the difference between all possible pairs of words ("emotion–emotion", "emotion–color", "color–emotion", and "color–color"). The participants were instructed before the experiment and then the first word was shown on the screen, followed by the second word. The participants had to give a subjective estimate of the difference between the current stimulus and that shown before, on a scale from 1 (minimal difference) to 9 (maximal difference). The current stimulus remained on the screen until the participant responded. Once the difference between the current and previous stimuli was given, the next stimulus was presented and remained until the participant responded.

Each series included the presentation of all possible pairs of stimuli from the matrix (a total of 20*(20–1) = 380 estimates of differences). Each participant took part in five experimental series, in which each of them gave a total of 1,900 estimates assessments of the difference between the stimuli. Prior to the main study, the participants subject took part in a trial series containing 190 comparisons (to actualize the associative connections between the stimuli and to form an appropriate scale of subjective differences), which was not included in the data.

The participants. The sample included 102 participants, native speakers of Russian (52 females), with an average age of 22.9 ± 3.7 (17–36) years. All participants had at least secondary-level education and normal or corrected to normal vision and color perception.

Data processing. The results of study for each participant were averaged over all five series to obtain a 20*20 matrix. After that, all these matrices for the 102 participants were averaged to yield the final matrix. To check the symmetry of the estimates in terms of the order of stimuli in pairs of the type A-B and B-A (where A and B are words from the set of 20 stimuli), correlation was calculated for the top and bottom triangular submatrices. The high correlation coefficient obtained shows the process of assessing the differences between stimuli to be symmetrical and allows averaging the matrix, relative to its diagonal, to obtain a symmetrical matrix suitable for multidimensional scaling. After that, two symmetrical color and emotional 10*10 submatrices were extracted from the symmetrical 20*20 matrix. Each of the three matrices was processed by multidimensional scaling with the Proxscal module in the SPSS 19.0 statistical package, with interval and ordinal transformation of proximities and a Euclidian metric. After making a decision regarding the dimensionality of each of the three spaces, we used an iterative procedure to find the center of the sphere maximally equidistant from all stimuli points. Thus, the stimuli points lie within a spherical layer with a thickness determined by some deviation from the radius of the sphere. The sphericity of the model was evaluated by the "coefficient of deviation from sphericity" (CDS), calculated as the ratio of the standard deviation to the mean radius. The configuration of points can be acceptably approximated by a sphere if the CDS does not exceed 10–15% (Izmailov & Sokolov, 1992; Paramei, Izmailov, & Sokolov, 1991; Sokolov, 2013).

If the sphericity hypothesis is accepted, the center of coordinates is placed in the center of the sphere and the configuration obtained is subjected to orthogonal rotation, following the literature on the nature of the axes of color and emotion spaces (Posner, Russell, & Peterson, 2005; Sokolov, 2013). Multidimensional scaling with transformation of proximities by an interval scale was used for parallel analysis of the stress curves obtained for color, emotional, and integral spaces, and nonmetric multidimensional scaling (the transformation of proximities by an ordinal scale) was used for the separate, more precise, analysis of the integral space.

Results

Table 1 gives the 20*20 matrix averaged over all runs of all participants.

Pearson's correlation coefficient between the top and bottom triangular submatrices was 0.988 ($p < 0.001$), allowing the matrix to be averaged relative to the diagonal. After interval multidimensional scaling and rotating, three models were constructed: one of color semantics, one of emotional semantics, and an integral model. Figure 1 gives the corresponding stress plots.

Table 1

*Matrix 20*20, averaged over the runs of all participants*

	anger	interest	disgust	sadness	contempt	happiness	calmness	fear	shame	surprise	white	sky blue	yellow	green	red	orange	grey	blue	violet	black
anger	0.00	7.06	3.91	5.88	4.05	7.66	8.13	4.37	4.91	6.67	7.27	7.54	6.37	7.42	3.09	5.50	6.44	6.89	5.90	3.88
interest	6.99	0.00	7.22	7.13	7.36	3.57	5.76	6.42	6.66	3.23	5.14	5.30	4.15	4.55	4.11	3.96	7.26	5.32	5.60	7.38
disgust	4.01	7.63	0.00	5.72	2.86	8.13	7.36	4.39	4.55	6.99	7.43	7.06	6.21	6.38	5.88	6.67	5.03	6.73	5.45	4.59
sadness	5.52	7.05	5.46	0.00	5.22	7.92	5.03	4.84	4.86	6.83	5.50	5.08	6.68	6.15	7.31	7.52	2.86	4.60	4.61	3.32
contempt	3.77	7.23	3.12	5.33	0.00	7.78	7.00	4.76	4.15	6.70	6.77	6.76	6.06	6.64	5.65	6.68	4.72	6.59	5.44	3.90
happiness	7.67	3.75	7.97	8.10	7.93	0.00	5.21	7.69	7.70	3.67	4.51	4.73	3.32	4.70	3.57	3.26	7.57	5.94	6.25	7.91
calmness	8.16	5.65	7.57	4.82	7.10	5.08	0.00	7.68	7.31	6.52	2.53	2.90	6.16	3.76	7.44	6.85	3.75	3.44	5.15	6.25
fear	4.51	6.59	4.71	5.04	4.80	7.56	7.69	0.00	4.12	6.41	6.61	6.86	6.36	6.99	5.16	6.77	4.89	6.47	5.43	3.63
shame	4.86	6.91	4.31	5.26	4.61	7.47	7.13	4.45	0.00	6.66	6.48	6.39	5.80	6.89	4.47	6.41	4.98	6.14	5.72	4.42
surprise	6.46	3.40	6.73	7.09	6.63	3.50	6.24	6.08	6.58	0.00	5.58	5.57	4.71	4.98	4.86	4.19	7.38	5.72	5.60	7.32
white	7.32	5.29	7.26	5.20	6.90	4.65	2.90	6.72	6.61	5.72	0.00	3.66	4.43	5.88	6.69	6.16	3.53	5.29	6.57	7.50
sky blue	7.36	4.82	6.87	4.68	6.63	5.10	2.98	6.69	6.49	5.57	3.73	0.00	5.88	4.44	6.58	6.51	4.31	2.34	4.18	6.55
yellow	6.31	4.27	5.79	6.44	5.88	3.40	6.10	6.31	5.38	4.53	4.72	5.90	0.00	4.49	3.96	2.55	6.33	6.18	6.51	6.91
green	7.25	4.71	6.39	6.04	6.48	4.75	3.84	6.94	6.45	5.21	5.77	4.28	4.41	0.00	6.42	5.75	6.05	4.26	5.79	6.35
red	3.04	4.25	5.78	7.08	5.81	3.77	7.66	5.06	4.93	4.91	6.52	6.89	3.78	6.56	0.00	2.73	6.84	6.67	4.78	6.14
orange	5.56	4.03	6.33	7.45	6.50	3.34	6.54	6.64	6.10	4.27	6.21	6.40	2.63	5.98	2.74	0.00	7.01	6.79	6.32	7.02
grey	6.02	7.00	4.98	3.06	4.60	7.29	4.18	4.92	5.13	7.17	3.52	4.43	6.29	6.03	7.14	7.09	0.00	4.81	5.82	3.30
blue	7.04	5.42	6.41	4.74	6.15	5.54	3.61	6.26	6.43	5.79	5.46	2.32	6.32	4.42	6.51	6.68	4.72	0.00	3.56	4.38
violet	6.01	5.76	5.72	5.11	5.45	6.15	5.48	5.73	5.59	5.78	6.67	4.01	6.53	5.98	4.86	6.28	6.11	3.51	0.00	4.77
black	3.93	7.42	4.36	3.49	4.36	8.16	6.33	3.49	4.82	7.37	7.72	7.00	7.15	6.92	6.08	7.24	2.95	4.80	4.76	0.00

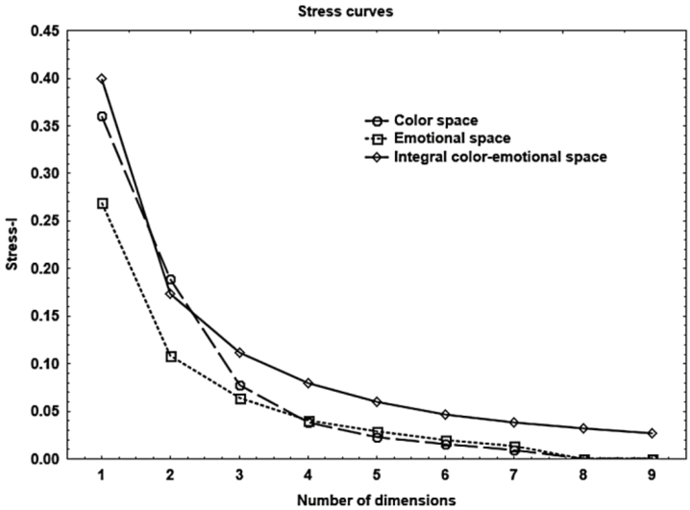

Figure 1. Stress curves

To more precisely identify the structure of the integral space, the 20*20 matrix was also processed by the method of nonmetric multidimensional scaling**.**

Based on the curvature of the scree plot and the threshold value of the stress, we decided to construct a four-dimensional model in each of the three cases. The CDS in each of the three models was found to be less than 8% (for color = 6.4%, for emotion = 7.12%, for color–emotion = 7.58%), suggesting that the stimuli lie close to the surface of the sphere of fixed radius. Tables 2, 3, and 4 give the coordinates of the four-dimensional solutions obtained after rotation.

Table 2

Coordinates of the four axes of the rotated color space (interval multidimensional scaling, stress I, Kruskal formula = 3.8%, coefficient of deviation from sphericity = 6.4%)

	X1	X2	X3	X4
white	–0.071	0.183	0.935	–0.511
sky blue	0.785	0.143	0.556	–0.212
yellow	–0.542	0.212	0.440	0.523
green	0.360	0.852	0.100	0.507
red	–0.369	–0.698	–0.129	0.563
orange	–0.470	–0.343	0.352	0.803
grey	–0.051	0.227	–0.022	–0.907
blue	0.879	0.235	–0.079	–0.177
violet	0.777	–0.573	–0.266	0.075
black	0.024	–0.011	–0.902	–0.558

Table 3

Coordinates of the four axes of the rotated emotional space (interval multidimensional scaling, stress I, Kruskal formula = 3.9%, coefficient of deviation from sphericity = 7.1%)

	X1	X2	X3	X4
anger	–0.836	0.545	0.178	–0.320
interest	0.795	0.347	–0.413	–0.185
disgust	–0.954	0.307	0.068	0.290
sadness	–0.513	–0.700	–0.227	–0.305
contempt	–0.857	0.074	0.247	0.168
happiness	1.074	0.237	0.035	0.111
calmness	0.568	–0.850	0.023	0.023
fear	–0.711	0.294	–0.550	–0.428
shame	–0.724	0.086	–0.629	0.305
surprise	0.622	0.614	–0.085	–0.028

Table 4

Coordinates of the four axes of the rotated integral color–emotion space (nonmetric multidimensional scaling, stress I, Kruskal formula = 8.0%, coefficient of deviation from sphericity = 7.6%)

	X1	X2	X3	X4
anger	–0.882	0.584	0.069	–0.286
interest	0.823	0.445	0.180	–0.431
disgust	–0.913	0.074	0.562	0.179
sadness	–0.445	–0.861	–0.182	–0.091
contempt	–0.832	0.047	0.402	0.425
happiness	1.008	0.449	–0.077	0.077
calmness	0.678	–0.859	–0.010	0.162
fear	–0.788	0.042	–0.523	–0.347
shame	–0.709	0.132	–0.369	0.453
surprise	0.635	0.489	–0.453	–0.430
white	0.640	–0.505	–0.442	0.450
sky blue	0.618	–0.672	0.096	–0.224
yellow	0.443	0.508	0.158	0.499
green	0.657	–0.218	0.732	0.211
red	–0.037	0.884	0.069	–0.163
orange	0.392	0.912	0.074	0.178
grey	–0.292	–0.817	–0.131	0.273
blue	0.341	–0.682	0.359	–0.447
violet	–0.094	–0.225	0.368	–0.774
black	–0.909	–0.436	0.094	–0.304

Discussion

Color semantic model. Figure 2 gives planes of the subjective space of color semantics formed by four bipolar axes.

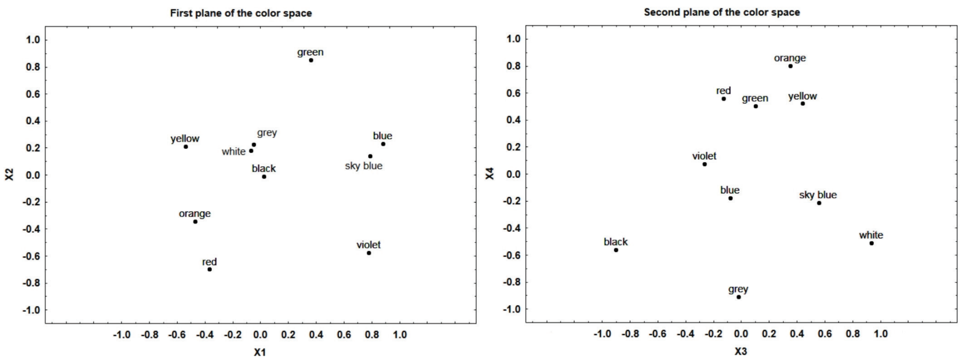

Figure 2. Subjective space of color semantics (left: a plane formed by the 1st and 2nd axes; right: a plane formed by the 3rd and 4th axes)

The first plane (axes 1 and 2), which is the plane of the hue, fully describes the configuration of colors with respect to one another. It shows the classical Newton circle (Izmailov & Sokolov, 1992), typical of subjective color spaces. The first axis of the color space is related to the classical opposition Blue–Yellow, the second axis to the opposition Red–Green, while the achromatic colors (black, grey, and white), as expected, occupy the center of the plane. The second plane (axes 3 and 4) is interpreted as the plane of Semantic Brightness and Contrast Grey. The third axis (Semantic Brightness) is organized such that black lies at the negative pole, while violet, red, blue, grey, and green lie nearer to zero; orange, yellow, and sky-blue lie further away, and white, the brightest color, occupies the positive pole. The fourth axis (Contrast Grey) has grey at the negative pole; the next colors are black and white; further away are sky-blue, blue, and violet; then green, yellow, and red; and at the positive pole orange, the color most opposed to grey. The fourth axis can be interpreted as a reflection of the activity of the "darkness neuron" at the semantic layer (see Sokolov, 2000, Fig. 3).

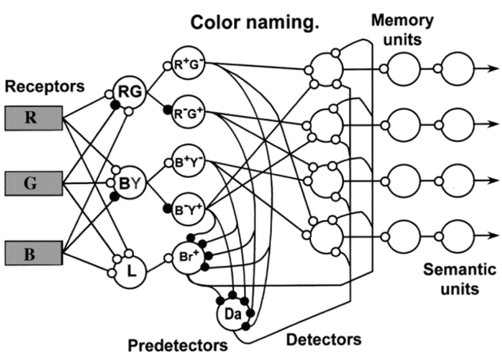

Figure 3. The network represents a local color analyzer supplemented by memory and semantic units (from Sokolov, 2000)

However, unlike in Sokolov's model, the fourth channel at the semantic level is not unipolar but opponent—i.e., the unipolar darkness neuron, tuned to grey, is opposed by a "contrast-grey neuron", tuned to orange.

The plane of saturation was constructed by a standard procedure developed in Sokolov's vector psychophysiology: 10 stimuli were distributed on a plane, the abscissa of which was the square root of the sum of the squares of the coordinates along the first and second axes, while the ordinate is the square root of the sum of the squares of the coordinates along the third and fourth axes (see Fig. 4), so saturation can be calculated as the angle between the planes of hue and brightness.

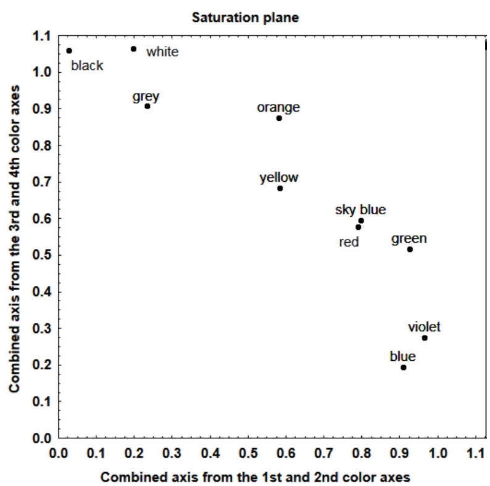

Figure 4. Saturation plane

As can be seen, the stimuli are located on a quarter of a circle (as predicted by Sokolov's spherical model), with saturation coded by the angle of deviation from the ordinate: Achromatic colors are the least saturated, and blue and violet are the most saturated. Note that saturation, if calculated like this, monotonically relates to but differs from the Brightness or Contrast Grey axes.

Emotion semantic model. Figure 5 gives the planes of the subjective space of emotional semantics formed by four axes.

The proposed model of emotional space is largely similar to the Russell circumplex model (Gerber et al., 2008; Yik, Russell, & Steiger, 2011) and the PAD model (Mehrabian & Russell, 1974; Valdez & Mehrabian, 1994); however, unlike the latter model, a fourth axis was identified.

The first plane is formed by the Valence and Arousal axes. The group of emotions at the negative pole of the Valence axis includes Disgust, Anger, Contempt, Shame, and Fear; further toward the center of the axis is the Sadness emotion. The emotions on the other side of the axis are Happiness, Interest, Surprise, and Calmness, among which Happiness is the most positive. The group of emotions at the negative pole of the Arousal axis includes Calmness and Sadness; the emotions on the positive pole are Anger and Surprise. We can see the classical configuration, corresponding to Russell's affective circumplex (Yik et al., 2011).

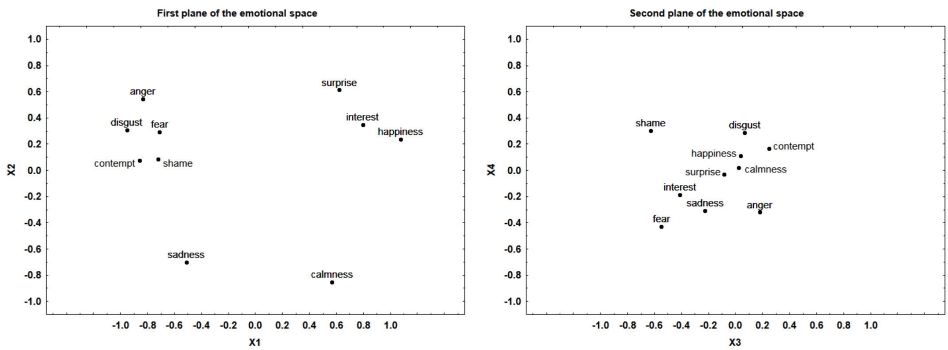

Figure 5. Subjective space of emotional semantics (left is the plane formed by the 1st and 2nd axes; right is the plane formed by the 3rd and 4th axes)

The axes on the second plane were interpreted as those of Dominance (vs. Submissiveness) and Social Rejection. The axes in this plane show much less variance (by about half) than those in the first plane. This may be attributed to the fact that the social aspect of these emotions, which is reflected by these axes, is secondary to the basic axes of Valence and Arousal. In the first plane, we see the basic projection of emotions, while the second plane shows separately the social aspects of the same emotions. The Dominance axis is formed by the opposition of the pairs of Anger and Contempt vs. Fear and Shame. The axis of Social Rejection is underlined by the opposition of the pairs of Contempt and Shame vs. Anger and Fear. The emotions of Anger and Fear are complementarily combined: Fear is the response of the subject to Anger directed against him. The emotions of Contempt and Shame are also complementarily combined: Shame is the response of the subject to Contempt directed against him. The passage from Fear to Shame and, in parallel, from Anger to Contempt, is accompanied by an increase in Social Rejection; Shame is associated with fear of social rejection, and Contempt is associated with Anger directed against the object of social rejection.

The plane of axes 1 and 2 is a "basic" plane, as the opponent axes described have a universal nature, common to humans and animals, coinciding with the Russell circumplex (Kuppens, Tuerlinckx, Russell, & Barrett, 2013; Kuppens et al., 2017; Yik et al., 2011), and have about twice the extent of the axes of the second plane. The plane of axes 3 and 4 can be referred to as "social" plane, because the oppositions described in it originate from the interaction of subjects in the field of social relationships (see also Landa et al., 2013). The Social Rejection axis, added to Dominance, makes the description of the social aspect of emotional functioning more complete.

Such division can be found in the literature on vector psychophysiology, where a model of elementary two-channel modules of coding various aspects of simulation is described (Sokolov, 2013). In that model, the processing of a complex stimulation is associated with simultaneous activation of several two-channel modules, the activity of which is coordinated according to a spherical law—i.e., for any two stimuli, the square root of the sum of the squares of their coordinates is a constant (the length of the radius-vector). The correctness of this approach was demonstrated for the perception of brightness, color, and orientation of visual stimulation (Sokolov, 2013). The model of emotional semantics we described can also be regarded as consisting of a pair of two-channel modules, one specialized in the coding of basic, universal emotional information, and the other in coding a more particular social aspect, and these two-channel modules are interrelated with one another by a spherical law (the CDS is 7.1%, i.e., below the threshold value of 10–15%).

Comparing our emotional model, based on names of emotions, with Sokolov's four-dimensional model, which is fundamental for us and which used schematic faces (Sokolov & Boucsein, 2000; Boucsein et al., 2001), it is apparent that the global four-dimensional spherical architecture of the subjective space is the same, although the individual axes and their interpretations are somewhat different. In Sokolov's model, the first plane ("emotional tone") is formed by two opponent axes Pleasure/Unpleasure and Fear/Anger, and the second plane ("emotional intensity") is formed by a unipolar axis of neutrality and an opponent axis Arousal/Dearousal (Fig. 6).

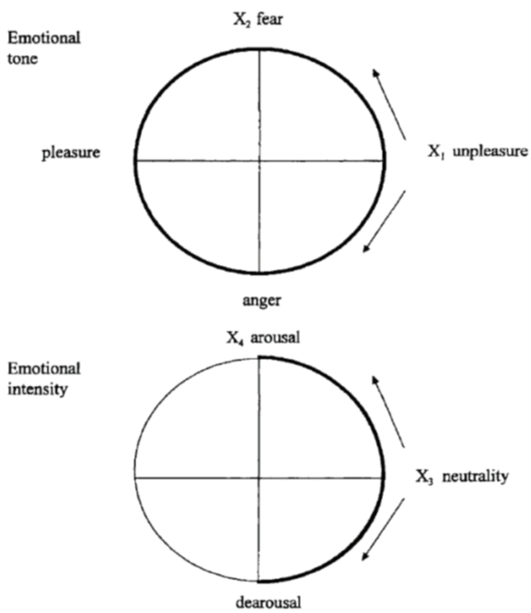

Figure 6. Model of emotional space from Sokolov and Boucsein (2000)

In our model, the first ("basic") plane is formed by two opponent axes, Valence and Arousal, and the second ("social") plane is formed by the opponent axis Dominance and the axis Social Rejection. An analogy can be established between Sokolov's Pleasure/Unpleasure and our Valence, between Fear/Anger and Dominance, and between Arousal/Dearousal and Arousal. Our model does not contain a unipolar axis of neutrality; instead we have Social Rejection.

Sokolov's model and the model we propose are systems of two two-channel modules interrelated by a spherical law; however, in Sokolov's model, these are the modules of emotional tone and emotional intensity, whereas in our model, these are the modules of basic and social emotionality. The difference between the models may be because the stimulation in Sokolov's model was represented by schematic faces, while our stimulation represented generalized emotional concepts. The passage from perceptual to semantic representation of emotions may be accompanied by some generalization, mediated by processes of social categorization and leading to a reduction of the axis of perceptual emotional neutrality and the actualization of a semantic axis of Social Rejection (however, the spherical mechanism of interrelation of the axes still functions). Another reason for the difference between the planes may be that the procedure of space rotation in the models was based on different conceptual criteria: Sokolov relied on an analogy with color space, while we used a comparison with Russell's circumplex model.

Integral model of color–emotion semantics. Figure 7 shows planes of integral subjective space, formed by four bipolar axes.

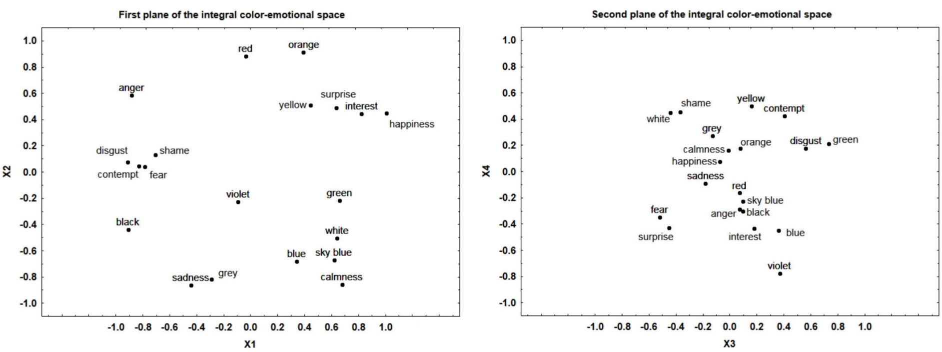

Figure 7. Subjective integral space of color–emotion semantics (left—the plane formed by the 1st and 2nd axes; right—the plane formed by the 3rd and 4th axes)

The first plane, as well as in the emotional space described above, is formed by Valence and Arousal. The first plane incorporates the color information from the two above planes of the color space—i.e., the integral color–emotion space is arranged primarily according to the emotional axes. This may be explained by the fact that the emotion evaluation system is more fundamental than the color system (Adams & Osgood, 1973). We can see a deformed Newton's circle inscribed into half of Russell's circumplex, formed by positive emotions (the first plane of the color space). This means that all chromatic colors are associated with positive emotions, with yellow and orange falling into the domain of active positive emotions; blue, sky-blue, and green are in the dearoused domain of positive emotions; red and violet were found to be rather emotionally neutral, and of these, red was found to be active, and violet was in the middle of the Arousal axis. White lay near the chromatic colors, while black and grey were in the emotionally negative part of the plane.

To describe the relationship of hue to Arousal and Valence, we consider the projection of Red–Green and Yellow–Blue into various domains of the integral space. The opposition of the red and green color characteristics is due to the opposition of the domain with neutral Valence and strong Arousal to the domain positive in Valence and moderately aroused. The opposition of the yellow and blue color characteristics is associated with the opposition of strongly and weakly aroused positive-Valence domains.

The deformation of Newton's circle may be associated, in particular, with the effect of information from the second plane of the color space—i.e., information about the Semantic Brightness and Contrast Grey characteristics of colors. Thus, the Valence on the first plane of the integral space nearly coincides with Semantic Brightness in such a manner that white, sky-blue, yellow, and orange are emotionally positive; grey, violet, and red are emotionally neutral; and black is emotionally negative. Arousal on the first plane of the integral space nearly coincides with Contrast Grey, such that the grey on the lower pole proves to be most unaroused; following it are black, blue, sky-blue, and white, followed by violet and green, with the most aroused being the colors on the upper pole—yellow, red, and orange.

Continuing the analysis of the first plane of the integral space, we can identify characteristic groups of stimuli, arranged along certain straight "isolines". Several "isoarousal" lines can be seen with stimuli in them not differing in Arousal but varying in Valence, along with several "isovalence" lines, which are orthogonal to the previous isolines and have stimuli not differing in Valence but varying in Arousal. All isoarousal lines are approximately parallel to the Valence, while all isovalence lines are approximately parallel to the Arousal. We can identify the following isoarousal lines (from dearousal to strong arousal): calm, grey, sadness; white, sky-blue, blue, black; green, violet, shame, fear, contempt, disgust; happiness, interest, surprise, yellow, anger; orange, red. Similarly, we can identify the following isovalence lines (from displeasure to pleasure): black, contempt, fear, disgust, shame, anger; sadness, grey, violet, red; blue, yellow, surprise, orange; calm, sky-blue, white, green, interest, happiness. We can see that the opposition blue vs. yellow is parallel to the isovalence lines, while the opposition red vs. green forms 45° angles with the isovalence and isoarousal lines, and the brightness opposition black vs. white is parallel to the isoarousal lines.

Let us analyze the second plane of the integral space (Fig. 7, right). The configuration of colors does not form either a systematic Newton's circle or axes of Semantic Brightness and Contrast Grey. This means that, as compared with the first plane, the color here is even more suppressed by the emotions. The configuration of emotions forms two orthogonal characteristics, which correspond to the previously identified Dominance and Social Rejection. On the positive pole of the Dominance axis is a cluster of semantic objects including disgust, contempt, green, blue, and violet; a lesser load falls onto the cluster including anger, red, yellow, orange, black, interest, and sky-blue, whereas the negative pole of the Dominance axis includes fear, surprise, white, and shame. On the positive pole of Social Rejection is a cluster of semantic objects that includes shame, contempt, white, and yellow; closer to the negative pole is the cluster of fear, black, anger, and sky-blue, while on the pole itself is the cluster of violet, blue, interest, and surprise. We can see that, moving from emotional to color-emotional stimulation, which potentially actualizes more diverse affective tones and oppositions, the axis of Social Rejection acquires a distinct opponent pole in the form of the emotions of interest and surprise. This agrees well with the behavioral interpretation of these emotions: social rejection and interest are opposing behavioral patterns.

Now let us compare our results with those of Adams and Osgood (1973), in which projections of the names of the basic colors into the space of Evaluation, Activity, and Potency were obtained in a large-scale cross-cultural study. Our data coincide with the data of that study in that black and grey are classified as emotionally negative colors, while white, blue, and green are emotionally positive; black and grey are nonactivated colors, and red is activated; the scale white–grey–black is close to the Evaluation axis. Deep analysis of the distribution of points suggests some inverse relation between Osgood's Potency and our Social Rejection; no relationship was found between our Dominance and Osgood's data.

Comparing our results with those of Valdez and Mehrabian (1994), we can see a full confirmation of the close correlation between Valence and Semantic Brightness (the positive emotional pole contains happiness, calm, and interest, and the brightest colors—white and sky-blue; the negative emotional pole contains anger, disgust, contempt, fear, and shame, and the darkest color—black). Our data on the close correlation between Arousal and Contrast Grey are similar to the data of Valdez and Mehrabian on Arousal and Saturation (Saturation is not represented as a separate axis in our four-dimensional model; it can be calculated only as the angle between the planes of hue and brightness). Figure 7 (right) demonstrates that Dominance, in addition to the transfer from white to green, also includes a local passage from white to grey and further to black. This coincides with the inverse relationship between Dominance and Brightness identified by Valdez and Mehrabian.

The analysis of Figs. 3–5 in Valdez and Mehrabian (1994), which reflect chromatic information, shows that the cluster of green, sky-blue, and blue, identified in Fig. 3 as the chromatic colors that have maximal positive estimates, fully coincides with our data. The plot correlating Arousal with Hue, given in Fig. 4, does not agree with our data; this may be attributed to statistically insignificant differences within Valdez and Mehrabian's data. A comparison of their Fig. 5, which reflects the relationship between Dominance and Hue, with our data shows the coincidence of the tendency toward green hues being closer to the pole of high Dominance.

The significant differences between our data and those of Valdez and Mehrabian are likely due to the different nature of the stimulation used in the studies. In our study, the color information was represented at the semantic level of representation, while they used the specific color charts of the Munsell system.

Analysis of four-dimensional emotional and color-emotional spherical models proposed in our study shows that these models can be treated as expansions of models suggested by Osgood (EPA), Mehrabian and Russell (PAD), and Russell (affective circumplex) and are substantially similar to the spherical models suggested by Sokolov.

The described axes of emotions have a complex neural basis. Possible brain mechanisms could be found in Sokolov and Boucsain (2000) and in Posner et al. (2005). In Sokolov and Boucsain (2000), specific balance of emotion-related neurotransmitters is believed to be the primary base of emotion. The information is gathered by two layers of subcortical "predetectors" (neuronal channels) and related basal ganglia emotional learning areas before it converges on cortical emotional detectors. For the predetectors that form Pleasure/Unpleasure (our Valence), the following areas are suggested: the lateral hypothalamus (1st layer), the anterior thalamic nucleus (2nd layer), and the nucleus accumbens at the emotional learning level. For Arousal/Dearousal, the reticular formation (1st layer) and the thalamic intralaminar nuclei (2nd layer) are suggested. For Dominance, similar to fear/anger as proposed by Sokolov and Boucsain, the ventral hypothalamus (1st layer), the medial thalamic nucleus (2nd layer), and the amygdala at the emotional learning level are suggested. Neural mechanisms for two emotional axes forming the affective circumplex suggested in Posner et al. (2005) substantially overlap the aforementioned data. For Valence, the mesolimbic dopamine system and asymmetry in frontal activation are suggested, and for Arousal, the reticular formation, the thalamic intralaminar nuclei, and the amygdala are suggested. In a more recent fMRI study (Posner et al., 2009), emotion-denoting words were used (similar to our approach) and the following areas were found to be related to Valence: the left insular cortex, the right dorsolateral prefrontal and precuneus cortices; and those related to Arousal were the left parahippocampus, the dorsal anterior cingulate cortex, the left dorsolateral prefrontal cortex, and the dorsal cerebellum. The abnormality of neural mechanisms in these two axes was also studied in autism spectrum disorders (Tseng et al., 2016). The neural basis for Social Rejection may include the anterior insula (bilaterally), the left anterior cingulate cortex, and the left inferior orbito-frontal cortex (Cacioppo et al., 2013).

The data gathered in our psychophysical study represent four emotional axes that could have the aforementioned neural mechanisms. The existence of a complex inter-modal neural mechanism that integrates color into a wider framework of emotions on the semantic level could be proposed. Further neuroimaging studies are required to examine this mechanism. Our preliminary research indicates that the default mode network could serve as this mechanism (Kiselnikov et al., 2018; Kozlovskiy et al., 2018).

Conclusion

Our study has shown that the best-fitting models for color and emotional semantics and for the integral color-emotional semantic are the four-dimensional spherical models that support the universality of the spherical model proposed by E.N. Sokolov (2013). The original method developed in our study allowed us to successfully actualize and measure color–color, emotion–emotion, and color–emotion semantic connections in a uniform metric. We were able to describe how colors and emotions interact on the semantic level, with the help of generalizing mechanisms of categorization. The data clarify the fundamental mechanisms of intermodal interaction of color and emotion at the semantic level, and open perspectives for practical use of this knowledge in applied psychology, ergonomics, psychodiagnostics, clinical psychology, psychophysiology, and cognitive neuroscience.

Limitations

The first limitation is related to the set of stimuli that was used in our study; this set was not broad enough to represent the full diversity of emotions and colors at the semantic level. The second limitation is related to all participants being Russian-speaking, which limits the possibilities of generalization.

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What Are You Thinking About Where? Syntactic Ambiguity between Abstract Arguments and Concrete Adjuncts in Hungarian, Modulated by Concreteness

Bálint Forgács[a,b*] & Csaba Pléh[c]

[a] *Department of Cognitive Psychology, Eötvös Loránd University (ELTE), Budapest, Hungary*

[b] *Hungarian Academy of Sciences (MTA), Budapest, Hungary*

[c] *Department of Cognitive Science, Central European University (CEU), Budapest, Hungary*

* Corresponding author. E-mail: forgacs.balint@ppk.elte.hu

Background. The critical importance of lexical concreteness and embodied sensorimotor processes for language comprehension is often assumed to be beyond doubt. Hungarian grammar is unique in that it expresses certain verb arguments using spatial suffixes, which sometimes create ambiguity between literal spatial adjuncts and abstract verb arguments.

Objective. In the present study, our goal was to investigate the role and perhaps primacy of concrete spatial meaning when generating the abstract sense of arguments of mental verbs.

Design. Towards that end, we embedded ambiguous verb-noun constructs with both a possible locative adjunct reading (i.e. spatial, literal) and a verb argument reading (i.e. abstract, figurative), with a continuously varying preference for one or the other, in disambiguating sentence contexts. Using a self-paced reading paradigm, we measured reading times of verbs and sentence final nouns of the ambiguous constructs.

Results. We found no difference in the reaction times to verbs, which suggests that their argument frames were obligatorily activated regardless of sentential context. Nouns were read more slowly in the argument contexts, yet the slower pace was driven by constructs that had a preferred locative reading.

Conclusion. This pattern of results contradicts strong embodiment explanations, and can be better accounted for by dual coding theory. Our findings demonstrate the importance of studying the role of concreteness and metaphoricity in linguistic meaning construction in the context of syntax and sentence processing.

***Keywords*:** sentence processing, embodiment, dual coding theory, arguments, spatial language, figurative language

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Introduction

In this paper we seek to bridge two distinct traditions of conceptualizing the construction of linguistic meaning. One of them looks at sentence parsing, centered around verbs and driven by expectancy, where verb arguments are thought to have primacy over external adjuncts (Kennison, 2002; Kintsch & Mangalath, 2011). The other relies on the dual coding theory of Paivio (1971, 2007) and embodiment (Lakoff & Johnson, 1999), both of which claim a superiority and primacy of concrete and perceptual meaning over abstract, purely linguistic meaning. Hungarian syntax allows the contrast of these two lines of research, due to the fact that in certain constructions spatial markers are not utilized in their concrete, literal, spatial meaning as adjuncts, but are exploited as grammatical arguments with an abstract, mentalistic meaning.

The idea that verbs play a central role in language representation and processing has been around for a rather long time. The peculiarity of verbs is related to their role of carrying sentential functions, thereby determining the grammatical role of noun phrases (NPs) for their various syntactic arguments. The seeds of this idea were already present in the logical model of predication proposed by Frege (1892/1984). Later it was raised again in different valence theories, first by Tesnière (1959), which introduced a chemical metaphor, where verbs are taken as complex stems that have different open slots, like the kernels of chemical compounds, and these slots are filled by NPs of various grammatical roles. A subsequent variant of the theory was case frames promoted by Fillmore (1968). The core of these ideas of sentence processing, detailed by various frame- and schema-based theories of understanding is, rather concisely, that sentence comprehension involves two basic stages (Schank, 1972; Kintsch, 1974):

1. Activate verb representations from long term memory storage, including their argument frames, together with the expected and likely arguments (such as Agent, Patient, Goal, Instrument, etc.).
2. Fill the argument slots with actual NPs from the incoming string.

Ensuing psycholinguistic experiments have indeed found facilitative effects between the processing of predicates and their arguments, which implied verb-based expectations towards certain types of arguments, be they called thematic roles or otherwise (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). For example, reading the verb *cut* facilitates the reading time of instrumental arguments (Kintsch, 1998; Kintsch & Mangalath, 2011). There have been intense discussions in the past century about how general (*cut* → instr) or how specific, lexical (*cut* → instr: knife) these expectations are. Other studies have shown that arguments are processed faster than adjuncts (e.g., Kennison, 2002), as adjuncts are optional, unlike arguments. The original goal of these theories was the detailed understanding of argument relations, which gave rise to the idea that Thematic Roles might be the key to the syntax-semantic interface in understanding (Carlson & Tanenhaus, 1988; Tanenhaus, Carlson, & Trueswell, 1989). However, the initial cognitively oriented theories were not particularly concerned with the exact grammatical markers employed by the system to assign argument roles to certain noun phrases.

Thematic Role assignment in sentence processing started to play a central role in syntax-based parsing theories (Ferreira & Clifton, 1986; Frazier & Fodor, 1978), with intense discussions regarding the automaticity and modularity issues. These considerations gradually raised the possible role of morphology, and its relation to semantic and cognitive issues concerning these expectation-based processes (for a review, see Pléh, Fekete, & Varga, 2017). Bornkessel and Schlesewsky (2006; Bornkessel-Schlesewsky et al., 2011) have run several behavioral, evoked potential, and imaging studies on sentence understanding in languages using different types of cues to argument roles (order, animacy, case marking, etc.). Independently of the specific cues, the Broca area always appeared to play an active role in assigning Thematic Roles. On the basis of these neuronal processing data, Bornkessel and Schlesewsky (2006) developed a full-fledged cross-linguistic theory of the temporal activation of verbal argument frames and the insertion of noun phrases into the slots as a second step.

In our work, we concentrate on oblique arguments of Hungarian verbs and capitalize on the fact that argument relations are coded by case markers in Hungarian (Kiefer, 1987, 2003). In such a language, argument processing and Thematic Role assignment are particularly closely tied with morphological processing. At the same time, there is a distinctive relation between morphological marking on NPs and the abstract/concrete semantic distinction. Most arguments of abstract, mental relational verbs (e.g., *to think, to remember, to fear*) are coded by spatial case markers, which otherwise denote locational relationships for verbs concerning physical position (e.g., *to put, to take, to go*). For example, the concrete, spatial relation in the Hungarian sentence *János elfordult a kutyától* ("John turned away from the dog") is expressed by the ablative suffix *–tól/-től* ("from"). But the same suffix is used in an abstract sense in the sentence *János fél a kutyától* ("John is afraid of the dog"). This alternation of the physical and abstract sense of suffixes sometimes leads to ambiguities when a given NP could be either an abstract argument or a concrete adjunct. There has been much discussion about how to differentiate arguments from adjuncts in Hungarian (Alberti, Farkas, Szabó, 2015; Komlósy, 1994). Table 1 illustrates some of these intricacies (for more examples, see Pléh et al., 2017). Regarding language comprehension, these ambiguities also raise the question whether there is a preference for the concrete (adjunct), or for the abstract (argument) during sentence processing.

Table 1

Varieties of the morphology of some argument frames in Hungarian

Construct type	Example	Gloss
Unambiguous construct Abstract (mental) argument	Emlékszik a fiú**ra** Haragszik a tanító**ra**. Készül a verseny**re**.	Remembers the boy-ON Angers the teacher-ON Prepares the race-ON
Ambiguous construct Abstract argument Concrete locative adjunct	Gondolkodik a lány**on.** Gondolkodik a haj**ón.**	Thinks girl-ON Thinks boat-ON

There are, of course, ambiguous argument frames in English as well. The sentence "John decided on the boat" can be interpreted either as John chose the boat or that he made his decision while being on the boat (Hornstein & Weinberg, 1981). In English these cases arise from a structural ambiguity based on the attachment height of the prepositional phrase (PP; in the cited example, the PP is "on the boat"). In Hungarian, however, such examples are related to the case suffixes of nouns. When a verb argument, which is syntactically closer to the predicate than a locative adverb, is expressed using a spatial metaphor, the figurative meaning becomes the part of the sentence structure that grammatically cannot be omitted. Since the argument is expressed using a suffix, grammatical complexity does not play a role in Hungarian when abstract figurative meaning has a syntactic function.

Some initial studies on argument structure processing in Hungarian have shown that the interaction between morphology and sentence comprehension is an intricate issue. Gervain and Pléh (2004) showed that prenominal verbs facilitated the processing of sentences ("Anna was thinking of the boat"), as opposed to sentences where nouns preceded verbs ("It was the boat Anna was thinking of"), which conforms to the idea that verbs activate their argument structure, and consequently, have a facilitative effect towards morphological endings coding for the arguments. Moreover, irrespective of word order, constructs with nouns referring to unambiguous concrete locative adjuncts were processed quickly, but processing slowed down when nouns referred to arguments that were unambiguously abstract, or ambiguous between the concrete locative and an abstract argument reading. Compare "Anna RUMINATED on the boat" versus "Anna RUMINATED on the problem", where the locative meaning is excluded in the latter case due to the mentalistic meaning of the NP *the problem*. This finding in and of itself suggests that we quickly and obligatorily activate the concrete meaning of spatial markers, even for abstract arguments, just as embodiment would predict (Lakoff & Johnson, 1999). However, when examining the reaction times for verbs requiring arguments, most of them were read more slowly when they referred to ambiguous as opposed to unambiguous arguments, that is, when the semantics of the NP excluded a concrete spatial adjunct reading (as in the above example). This latter finding hints at just the opposite explanation: The abstract meaning could be activated independently of the concrete locative meaning, and the slowdown in the ambiguous conditions is due to a parallel activation of the two. The authors interpreted their findings in a sentence-processing model where a verb-based expectation arrow would obligatorily point towards the argument, and ambiguous arguments are read more slowly because of a parallel activation of the argument and a locative meaning. This is in line with dual coding (Paivio, 2007), in fact, which suggests that all words activate a purely linguistic, amodal code, whereas concrete words activate an *additional* imagistic code and this might happen in the case of ambiguous constructs. In sum, the reading times of the sentences as a whole and that of verbs with arguments produced an inconsistent pattern in terms of processing the abstract and concrete.

The aims of the present study

Gervain and Pléh (2004) reported verb reading times, on the one hand, that allowed for a dual coding interpretation, where the abstract argument structure would be the amodal, purely linguistic code, which is always activated, and if the morphological marker is a concrete, spatial suffix, there is an additional activation of the imagistic code for the literal meaning. Note that Paivio originally proposed the parallel activation as an explanation for the *faster* reaction times for concrete words. However, rather sophisticated and rigorously controlled experiments recently revealed a slower reaction time for concrete words (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011). The sentence-reading times of Gervain and Pléh (2004), on the other hand, suggest that locative adjuncts are processed quickly, and abstract arguments are processed as slowly as ambiguous ones. This finding implies that it is the activation of the concrete that can be carried out automatically, and it is the abstract meanings that are co-activated additionally, which is more consistent with embodied cognition (Lakoff & Johnson, 1999). The concrete should have primacy, and it is supposed to be obligatorily activated in order to provide content and conceptual structure to abstract concepts via metaphorical mappings (Lakoff & Johnson, 1980).

Experimental investigation of the basic proposals of embodiment are rather scarce. Even though a large number of studies have demonstrated the parallel activation of concrete and abstract meanings, the directionality of the effect, the primacy of the concrete, and the necessity of sensorimotor processes have not been backed by conclusive evidence. Forgács and colleagues (2015) found that even metaphors might not necessarily require imagistic and/or sensorimotor processes, even if they are constituted of concrete words, as reflected by the electrophysiological concreteness effect, which hinted that sometimes even concrete words might not require concrete senses.

We designed a Self-Paced Reading experiment, where we combined the processing of ambiguous morphological markers with a systematic manipulation of the abstract/concrete dimension to address the questions raised by the data of Gervain and Pléh (2004), and to further elucidate the primacy of the literal, concrete meaning in morphosyntactic aspects of sentence comprehension. To this end, we compared the processing of sentences ending in ambiguous verb-noun constructs that continuously varied in their preferred interpretation, leaning towards either an abstract argument or a spatial locative reading, all of which we embedded in two kinds of sentence contexts that allowed for either the locative or the argument reading. Although all sentences ended in concrete nouns and the same nouns appeared in both contexts, a concreteness effect could be expected, because based on electrophysiological studies, it seems to be driven not by lexical properties of single words but semantics of conceptual combination (Huang, Lee, & Federmeier, 2010) and sentence meaning (Holcomb, Kounios, Anderson, & West, 1999).

We intended to compare a number of possible temporal models, where processing advantage for the concrete or the abstract can be explored separately for verbs and nouns in locative and argument contexts. According to the conclusions of Gervain and Pléh (2004), all verbs should activate their full case frames in both conditions and irrespective of the preferred reading of the specific constructs. This process should yield no difference in reading times across contexts, since the same constructs and the same verbs are employed.

The processing of the nouns coincides with the wrapping up of the whole sentence. Based on Gervain and Pléh's (2004) sentence results, if the activation of verb frames is obligatory, constructs should remain ambiguous irrespective of context, and then there should be no reading-time difference between argument and locative contexts. If frames are activated flexibly and the context sufficiently determines meaning by the reading of the constructs, argument contexts should be read more slowly than locative contexts, as reported by Gervain and Pléh (2004). This would conform to embodied accounts as well, since the slower pace for the abstract argument would suggest serial processing and obligatory sensorimotor simulation of the concrete spatial meaning (cf. Gallese & Lakoff, 2005; Lakoff & Johnson, 1999). Constructs in a locative context would be fast irrespective of their preferred reading; constructs in argument contexts should be slower, because of the necessary co-activation of the spatial meaning, but those with a preferred locative reading could have a processing advantage relative to those with a preferred argument reading because of a pre-activation of the spatial meaning.

Novel results regarding the concreteness effect (Kousta et al., 2011) would predict a slowdown for the concrete locative context, perhaps because of the parallel activation of the abstract meaning. A facilitated processing of nouns in argument contexts could also be due to activated verb frames (Fillmore, 1968), where slots have been opened for an abstract mentalistic meaning. Such a non-perceptual sense of a concrete noun that could refer to a physical place could be understood in terms of Paivio's (2007) purely linguistic code, and/or as emotional content, as suggested by Kousta and colleagues' (2011) abstractness effect, or even as the mentalistic content attributed via Theory of Mind functions, in propositional format, to the verb's agreement (e.g., "thinking about the ship"). It should be noted that a frequency-based explanation would also predict faster processing for mentalistic arguments (Kornai, Halácsy, Nagy, Trón, & Varga, 2006).

A third possible outcome is that we might find no difference, which would also be informative: It would indicate that because verb arguments are expressed in Hungarian via spatial morphological markers, their abstract meaning has been conventionalized to the extent that they are lexicalized, much like the meaning of idiomatic expressions, and they are not processed any differently from concrete, literal, spatial language (e.g., Forgács et al., 2012).

Methods

Participants

In this study, 33 university students (4 female, age range: 18–22 years) participated for course credit. All of them were native speakers of Hungarian, had normal or corrected to normal vision, and had no history of neurological or psychiatric disorders. An additional 13 individuals were excluded from data analysis, because they did not retain at least five trials with correct responses per condition after outlier removal. Out of the 33 participants, only 25 were included in the analysis of sentence final target words for the same reason.

Stimuli

As a first step, 20 Hungarian ambiguous constructs were generated, where a spatial suffix allows for both a locative adjunct and a verb argument reading. Next, the ambiguous constructs like (1) were judged in a pretest by 51 raters who did not participate in the later experiment. They were rated on a 6-point Likert scale: Which meaning comes first, the abstract argument (2) or the concrete locative adjunct (3)?

(1) *Gondolkodtam a hajó**n**.*
"I was thinking the boatON." Allows both locative and abstract reading.
(2) *A hajó**ra** gondoltam.*
"The boatON was I thinking." Only abstract meaning allowed.
(3) *A hajó**n** voltam.*
"The boatON was I." Only locative concrete meaning.

According to the results of the pretest, the ambiguous constructs covered the whole range of preference from the argument to the locative reading (Figure 1). Following the pretest, each of the 20 constructs was extended with two antecedent contexts that set up the sentence to clearly have either a locative or an argument reading. For example: "I had pleasant memories about it, that is why I was nostalgic about the excursion" vs. "I was at the place in my childhood, that is why I was nostalgic on the excursion."

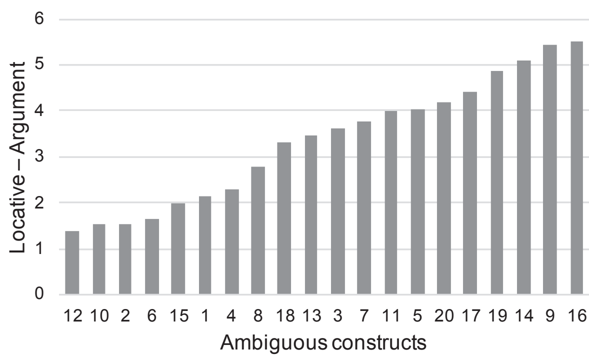

Figure 1. Results of the pretest for each ambiguous construct. The preferred reading of the constructs was relatively evenly distributed from the locative to the argument interpretation.

Experimental procedure

A Self-Paced Reading (SPR) paradigm (Just, Carpenter, & Woolley, 1982) was employed, where sentences were broken down to single words (nouns preceded by their articles) and presented individually until participants pressed a button, after which the next word appeared. Sentence final words were followed by a screen with an arrow pointing to the right, which was followed by test sentences concerning the ambiguous construct, identical with those of the pretest. The task of the participants was to verify whether the target sentence conformed to a locative adjunct reading or a verb agreement reading. Reaction times were registered for each word.

Every participant saw each construct only once, either in the locative or in the argument sentence context, but by employing two complementary lists, both variants were presented across participants.

Results

Reaction time measures for the verb (the word before the final word) and the noun with the ambiguous suffix (sentence final word) were analyzed using linear mixed-effects modeling (Baayen, 2008; Baayen et al., 2008), via R (R Core Team, 2017) and the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). Before data analysis we removed outlier data points 2 standard deviations away from the mean, separately for each participant, for responses faster than 200 ms and slower than 3000 ms, and items that were followed by an incorrect response. Participants were removed from later analyses if they did not have at least five correct responses per condition following outlier removal. Reaction times were log transformed for statistical analyses. The order of trials was included in the models as a fixed effect, since it significantly improved models of random effects only. Context (locative vs. argument) was entered in the models as a fixed effect, and the results of the Pretest with an interaction were added for nouns; random effects included items and participants as intercepts, and the latter incorporated random slopes for Context, to keep the random effect structure maximal (Barr, Levy, Scheepers, & Tily, 2013). Residual plots did not reveal obvious deviations from homoscedasticity or normality.

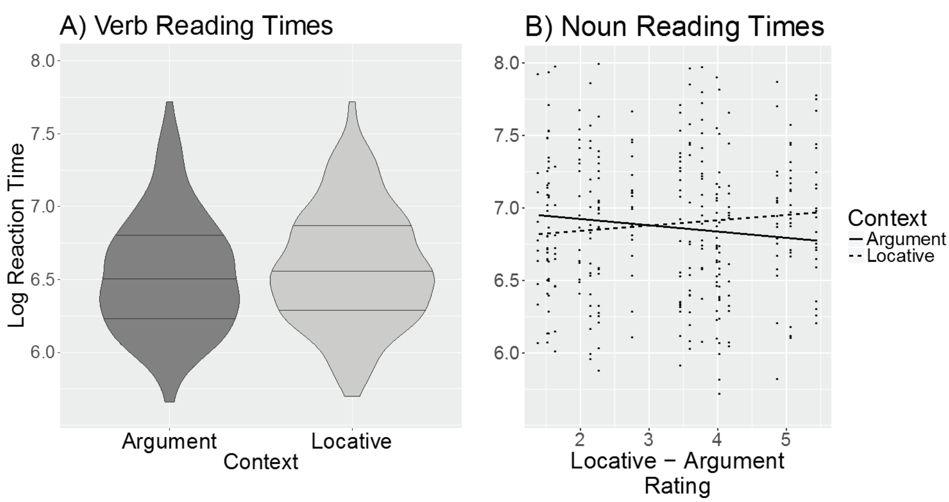

Figure 2. Violin plot of reading times (log reaction times) to verbs in the two contexts, where horizontal lines represent quartiles (A). Reading times to sentence final nouns are plotted against the preference for the argument or the locative reading of the ambiguous constructs according to the pretest (B), where fitted lines show the sentence context in which constructs were embedded. There was no reading-time difference for verbs, while sentence final nouns were read more slowly in argument contexts, but the effect was driven by constructs that had a preferred locative interpretation.

First, we analyzed reaction times for reading the verbs, but we found no significant effect of Condition [$\beta = -0.01$, $SE = 0.01$, $F(1, 385) = 1.06$, $p = .30$] (Figure 2A). Reaction times following sentence final nouns revealed a significant main effect of Context [$\beta = -0.13$, $SE = 0.06$, $F(1, 292) = 4.68$, $p = .031$], with nouns being read more slowly in the argument than in the locative context. There was also a significant interaction between Context and Pretest [$\beta = 0.04$, $SE = 0.02$, $F(1, 293) = 4.51$, $p = .035$], and when broken down by Context, a marginally significant modulation of reading times by preferred interpretation was revealed only for the argument context [$\beta = -0.05$, $SE = 0.03$, $F(1, 128) = 3.46$, $p = .065$] (Figure 2B).

Discussion

In the present self-paced reading experiment, we presented participants with ambiguous constructs that could either have a concrete locative reading or an abstract verb argument reading. The constructs varied continuously with regards to their preferred reading according to a pretest, but they were embedded in sentences that provided a disambiguating context for one interpretation or the other. With this experimental design, we sought to exploit a unique syntactic ambiguity of Hungarian language, where the same morphological marker can indicate a verb argument or the locative of a sentence, in order to investigate the morphosyntactic processing of spatial suffixes. Specifically, we intended to investigate whether the concrete or the abstract sense takes precedence, and whether either of the two requires the parallel activation of the other during the course of processing, when a spatial suffix is utilized to mark the arguments of verbs.

The results revealed no difference in reading times of verbs in the two conditions. This finding suggests that verbs activate their case frames, as proposed by frame semantics (Fillmore, 1968) and reported by Gervain and Pléh (2004): The full argument structure does seem obligatorily activated, hence the lack of difference between the two conditions.

Nouns in argument contexts were processed slower than in locative contexts, which suggests, in line with embodied cognition (Lakoff & Johnson, 1999), that the concrete locative meaning is accessed quickly, but the abstract argument meaning is processed more slowly, perhaps because of the parallel activation of the literal spatial meaning. It also conforms to classical, facilitatory concreteness effects (Paivio, 2007), that is, shorter reaction times to concrete words than for abstract words, which raises the possibility that concrete words are processed faster in a concrete sense than in an abstract sense — even if abstract words are the fastest.

However, the significant crossover interaction between context and the preferred reading puts the results in an entirely different light. The preferred reading of ambiguous constructs modulated reading times significantly only in argument contexts, and they slowed down reaction times only for constructs with a preferred locative reading (and not for a preferred argument reading). This result contradicts embodiment, because it should be just the other way around: Reaction times should be slower for the argument reading due to the necessary activation of the spatial meaning of the suffix. There are two possible explanations. First, processing could be more context dependent: An ambiguous construct with a preferred locative reading could be read faster in a locative context and more slowly in an argument context — and vice versa — which could override concreteness. Second, the concrete sense could have been activated for constructs with a preferred concrete locative interpretation in the argument context, not for constructs with a preffered in the argument reading, and this could have been the reason for the overall slower processing. In other words, when the concrete meaning was primed, the abstract took no additional time to co-activate, perhaps because it had been activated already; but when the abstract meaning was primed, the concrete slowed processing down, which is in line with dual coding and the results of Kousta and colleagues (2011).

Taken together, these results suggest an intricate pattern of meaning activation and processing of ambiguous constructs with a spatial suffix that can have both a locative and an argument reading. Verb frames seem to be activated obligatorily, irrespective of context, and to be filled rapidly. The modulation of reaction times for nouns is better explained by the dual coding theory (Paivio, 2007), as reinterpreted by Kousta and colleagues (2011), than by embodiment. Further studies are necessary to confirm and refine our findings, which should be taken with a grain of salt, because of the low number of test sentences and high number of excluded participants. In conclusion, our results on the processing of ambiguous spatial suffixes indicate that the issues of concreteness and embodiment, as well as of grammatical metaphors, should be studied at the level of complex syntactic structures rather than solely at the level of individual words.

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The Relationship of Language and Intelligence Development to the Maturity of the Subcortical Structures in Children with Specific Language Disorders

Victoria L. Efimova[a], Elena I. Nikolaeva[b*]

[a] *Prognoz neurological clinic for children, Saint Petersburg, Russia*

[b] *Herzen State Pedagogical University, Saint Petersburg, Russia*

* Corresponding author: E-mail: klemtina@yandex.ru

Objective. To detect possible dysfunctions of subcortical brain structures in children with severe disorders of language development and to study the association of such dysfunctions with linguistic and cognitive development, particularly the development of nonverbal intelligence on the level of the norm.

Design. 45 children with severe speech disorders, aged 4 to 7 years, took part in the study: 9 girls and 36 boys who were patients at the Prognoz neurological clinic for children (Saint Petersburg). The diagnoses according to ICD-10 were the following: F.80.1 — expressive speech disorder — 35 children; F.80.2 — receptive speech disorder — 10 children. The functional state of the brain stem was assessed by the auditory brain stem response (ABR) method. A modified stimulus was used to register peak VI, that is, a short tone burst with a frequency of 4,000 Hz, plateau duration of 0.5 ms, initial front of 0.5 ms, and intensity of 70 dB above the hearing threshold.

Results. Analysis of the evoked potentials gave the following results: Deceleration of vestibular and/or auditory information conduction on the level of brain stem structures was detected in 98% of the children. Deceleration of vestibular information conduction was manifested in increased latency of the positive wave P13 cVEMP in comparison with the normative value. Deceleration of auditory information conduction was shown in an increase of the peak intervals of ABRs in comparison with normative values.

Conclusions. All the children displayed conduction disturbances in the auditory and vestibular systems. Conduction disturbances in the auditory system were directly connected with the severity of their speech problems. Conduction disturbances in the vestibular system were associated with lower nonverbal intelligence.

***Keywords*:**
cognitive processes, language, subcortical structures of the brain, children, severe disorders of language development

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Introduction

The terms "cognitive processes" and "language" are entirely associated with the neocortex functions by the majority of researchers, since it is known that evolutionarily it is the cerebral cortex that distinguishes man from other animals. The familiar "horizontal" model of the brain implies analysis of the involvement of the right and left hemispheres in the development of these and other cognitive abilities and the exchange of information between the hemispheres (Friederici, 2012; Hagoort & Indefrey, 2014). But it does not take into account the contribution of the subcortical structures: the brain stem, the hippocampus, the cerebellum, the basal ganglia, etc. During recent decades, a considerable number of studies have been published that indicate that the subcortical structures take part not only in the movement and conduction of sensory information, but also in cognitive processes such as memory, thinking, and speech (Felix, Gourévich, & Portfors, 2018; Koziol & Budding, 2009; Kraus, 2001).

It is obvious that many speech abilities in a small child are quite well developed, despite the immaturity of the cerebral cortex (Werker & Hensch, 2015), since the neocortex reaches full functional maturity much later than the development of speech and many cognitive functions in normatively developing children. One may assume that structures of a lower order may be involved in a child's cognitive and linguistic development, structures related to the transmission of auditory information and orientation of the body in space. The role of the vestibular system in cognitive development is being actively discussed at the present time (Rine & Wiener-Vacher, 2013; Wiener-Vacher, Hamilton, & Wiener, 2013). This is connected with the fact that the brain, as it constructs a picture of the surrounding space, fixes it relative to the position of the head; that is why the vestibular system is active in almost all cognitive processes (Bigelow & Agrawal, 2015). The role of auditory information is associated with the sensorimotor integration that underlies both the production and understanding of speech (Basu & Weber-Fox, 2009; Bishop, Hardiman, & Barry, 2009; Leite, 2014). There are few works that have used auditory brain stem responses (ABRs) to register the deceleration of the auditory signal conduction on the level of the brain stem in children with developmental disabilities (Hornickel, 2011; Leite, Wertzner, & Matas, 2010) It is known that based on latency, three groups of acoustic evoked potentials are distinguished: short-latent, mid-latent, and long-latent. ABRs are short-latent potentials, fixed within a duration of 10 ms from the moment of acoustic signal production. This method is used in pediatric neurology for assessment of the integrity and functional maturity of the brain stem structures that participate in conducting auditory information. The absence of ABR components (peaks) or their gross deviation from the norm indicates brain stem dysfunction in the child (Abadi, Khanbabaee, & Sheibani, 2016; Choudhury & Benasich, 2011).

The study of ABRs also makes it possible to keep track of the recovery of sensory functions. An increase in the number of registered peaks and the reduction of latent periods indicate restoration of function (Efimov, Efimova, & Rozhkov, 2015). ABRs are detected even in the prenatal period, in the fetus aged 32-38 weeks. Their parameters allow us to evaluate the neurophysiological maturity of infants. The principal development of ABRs occurs by the age of 12 months, due to the myelination of nerve fibers (Choudhury & Benasich, 2011).

Myogenic potentials evoked by clicks are a clinical test of the sacculo-cervical reflex. When the ear is stimulated by a loud click, a stapes movement occurs, and the sacculus receptors of the otolith apparatus are activated. The afferentation passes along the lower vestibular nerve through the vestibulospinal tract and activates the motoneurons of the nucleus of the accessory nerve, which causes contraction of the sternocleidomastoideus muscle. In response to the click, registration of the contraction of the sternocleidomastodeus muscle allows evaluation of the functioning of the sacculus, lower vestibular nerve, and vestibular tract (Cal & Bahmad, 2009; Murofushi, 2014; Zhou, 2014).

These methods are used to assess the functioning of the otolith apparatus, which allows the organism to sense gravitation, gauge its head position in space, and react to changes in that position. Impairment of the otolith function in adults may lead to full spatial disorientation. In children, most often, vestibular system dysfunction entails deceleration of motor and cognitive development, because the formation of body scheme projections in the cortex and the development of representations about space are performed on the basis of distorted perceptual signals (Rosegren & Kingma, 2013; Rosengren, Welgampola, & Colebatch, 2010; Young, 2015).

J. Ayres, the author of sensory integration theory, believed that full-fledged vestibular afferentation, which is an organizing factor for all sensory information, is remarkably important for the cognitive and motor development of the child (Ayres, 1972). Wiener-Vacher et al. (2013) provided evidence of the importance of the vestibular system for the development of cognitive functions in children related to orientation in space. They hypothesized that the loss of vestibular function before the critical stages of development would lead to specific cognitive deficits. Experiments on animals proved that the absence of vestibular stimulation before the critical periods of hippocampus development leads to its atrophy. Wiener-Vacher et al. considered the ages of two, seven, and 11 years to be critical periods for hippocampus development.

Since the otolith organs react not only to vestibular information but also to low-frequency sounds, they are involved in the recognition of the intonation and rhythm of an utterance, which is crucially important for full communication, including language. It has been shown that the sacculus is necessary for speech perception amid background noise. It is also known that during lessons with a speech therapist, vestibular stimulation facilitates speech understanding by the child and enhances his or her speech activity (Ayres, 1972). That is why there is a need for further study of the interrelations between the auditory and vestibular systems (closely connected both anatomically and evolutionarily) and the influence of those interrelations upon a person's cognitive and language development.

One may suppose that part of a child's speech problems may be due, not to processes taking place in an underdeveloped cortex, but to a pathology on the level of the subcortical structures, caused by some peculiarities of the child's development at the earliest stages of ontogenesis, first of all during the prenatal period (Kraus, 2001).

Thus our present investigation sought to detect possible dysfunctions of the subcortical structures in children with severe disorders of language development, and the association of those dysfunctions with the level of language and cognitive development. A fundamental focus in our research is the development of nonverbal intelligence on the level of the norm in those children.

Materials and Methods

Forty-five children with severe speech disorders aged from 4 to 7 years took part in the study: 9 girls and 36 boys were patients at the Prognoz neurological clinic for children (Saint Petersburg). The proportion of boys and girls in our sample corresponded to the literature norm, since it is known that speech problems occur in boys more often than in girls (Dodd, 2013).

The diagnoses were verified by a neurologist and a speech therapist. The examinations were conducted at the direction of the neurologist as a diagnostic procedure, with written consent of the parents. The diagnoses according to the ICD-10 were: F.80.1 — expressive speech disorder — 35 children; F.80.2 — receptive speech disorder — 10 children. At the time of the study, 22 of the children communicated mostly through vocalization, with a vocabulary of fewer than five words; 12 children used one-word statements and a vocabulary of fewer than 20 words; and 11 children used simple phrases of two words and a vocabulary of more than 20 words.

The functional state of the brain stem was assessed by the auditory brain stem response (ABR), as registered by the NikoletVikingselect-TM analyzer (VIASYS Healthcare, Inc., USA). The following leads were used: mastoid on the left and vertex on the right. Every 500-1,000 evoked responses were summed (each 12 ms in duration) with no tracks, containing artifacts (automatically withdrawn if the threshold of amplitude discrimination of 30-40 mW was exceeded). The bandwidth of the signal was set in the range of 100 to 3,000 Hz. A click was used as the stimulus (polarity-rarefaction) with a duration of 0.1 ms and intensity of 70dB of hearing level. The peak latencies and amplitudes of the I, III, and V peaks were measured in the ipsilateral electrode relative to the stimulated ear. The amplitude was gauged in the range from the maximum positive to the maximum negative of the following wave. The time of central conduction was estimated (values of the intervals between waves I-III, III-V, and I-V). The stimuli were presented with headphones (NDH39), separately into the left and right ears, with a frequency of 10.1 Hz.

A modified stimulus was used to register peak VI, that is, a short tone burst with a frequency of 4,000 Hz, plateau duration of 0.5 ms, initial front of 0.5 ms, and intensity of 70 dB above the hearing threshold. The employment of this modified stimulus made it possible to determine the time of the auditory signal conduction through the brain stem from hair cells of the organ of Corti to the medial geniculate body of the thalamus. Peak VI was identified subject to the detection of peaks I, III, and V, given the standard stimulation. Five hundred to 1,000 representations on the left and right sides were averaged.

Vestibular function was evaluated by the method of cervical vestibular evoked myogenic potential (cVEMP). In response to acoustic stimulation, cVEMPs were registered by the Neuro-EMP-4 neuro-averager (Neurosoft, Ivanovo, Russian Federation). The latency of waves P13 and N23 of VEMP was assessed and registered from the sternocleidomastoideus on the side where the clicks were presented (the sacculo-cervical reflex). The clicks at 130 dB (ultrasound diagnostics) and 0.5 ms in duration were delivered by headphone. Four to 20 cVEMPs were averaged in 5 to 15 series with subsequent superposition to assess the reproducibility of the responses. Tonic muscle tension was triggered by the maximum rotation of the head to the side.

The child was sitting in an armchair during the registration of evoked potentials. None of the children had hearing impairments, according to the audiologists.

J. Raven's colored progressive matrices test was used to assess the intelligence of the subjects, using the Egoskop program facilities of the Medicom research and development company (Taganrog, Russian Federation) for objective testing and analysis. Variant 1 is for children aged 8 to 11 years. It consists of three series of different levels of difficulty, each containing 12 matrices with missing elements. The subject is presented with 36 tasks. Test variants 2 and 3 were used in the present study: variant 2 for children aged 6–8 years, consisting of two series (A and Av) — 24 tasks; variant 3 for children aged 4–6 years, consisting of one series (A) — 12 tasks. The subject was presented with pictures of figures on a monitor,. One figure was missing; it was presented beneath, among six other figures. The subject's task was to determine the pattern made by the figures in the picture and to indicate which figure was needed to complete the pattern, communicating in any way possible (pointing to it with a finger, putting the cursor on it, or identifying its number). Based on the percentage of correct answers, five levels of the children's intelligence were distinguished:

Level 1 (higher than 95%) — high intelligence;
Level 2 (75–94%) –higher than average intelligence;
Level 3 (25–74%) — medium intelligence;
Level 4 (5–24%) — lower than average intelligence;
Level 5 (lower than 5%) — intellectual defect.

All the data were processed with the SPSS-22 software package.

Results

Analysis of the evoked potentials gave the following results: Deceleration of vestibular and/or auditory information conduction on the level of the brain stem structures was detected in 98% of the children. Deceleration of vestibular information conduction was manifested in an increase of latency of the positive wave P13 cVEMP in comparison with the normative value. Deceleration of the auditory information conduction revealed itself in an increase of the peak intervals of ABR in comparison with normative values.

Regression analysis of the data was performed. Since nonverbal intelligence was not below average in any of the children, there was no association found between the severity of their speech problems and their nonverbal intelligence.

It was shown that the independent variables cVEMP P13 influenced the dependent variable "nonverbal intelligence". Moreover, since coefficient β had a negative value, there was an inverse relationship between the variables. That is, the higher the intelligence, the lower the amplitude of the wave and the greater the speed of vestibular information conduction. One might suppose that nonverbal intelligence was directly connected with the position of the head, which was determined by vestibular characteristics.

Table 1

Influence of the independent variable upon the dependent variable "nonverbal intelligence"

Independent variable	R2	B	P
cVEMP P13	0.420	–0.648	0.009

Factor analysis was performed with principal components analysis and the varimax rotation method. The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was equal to 0.510, which indicates the applicability of factor analysis to this sample. A three-factor solution was obtained, with 87% explained variance.

The total scores on the Raven test and cVEMP P13 (0.862) were included in the first factor with a greater weight (-0.910). This factor might be called the factor of the association between nonverbal intelligence and conduction in the vestibular system: The more effective that conduction, the higher the nonverbal intelligence. The second factor included the ABRs on the right according to the duration of the latent period of peak VI (0.807) and the cVEMPs on the left (0.797). It could be called the factor of unity and interaction of the parameters of the vestibular and auditory systems. The third factor included the peak interval of ABR III-V on the right (0.889) and the severity of speech disturbances (-0.884). This is the factor of the connection of speech impairment to conduction disturbance in the auditory system.

Factor analysis confirmed the data of correlation analysis about the relationship of speech problems to changes of conduction in the auditory system and the relationship of nonverbal intelligence to conduction parameters in the vestibular system. Moreover, it demonstrated the unity of the auditory and vestibular systems.

A statistically significant relationship was found between vestibular disturbances and nonverbal intelligence, as well as between the deceleration of auditory information conduction through the stem structures and the severity of language disorders.

No correlation was found between the severity of language development and the level of intelligence.

Discussion

We found a statistically significant relationship between the increase of the duration of peak interval III-V ABR and the severity of language disorders. This is consistent with the view that in the absence of speech in a child, the inability to transport stimuli from the surrounding world because of a deficiency in the conducting pathways was relevant, but organic lesions of the brain's cortical linguistic areas (Vizel', 2015) were not. As a result of these impairments, the cortex did not receive the necessary stimulation and could not develop fully. The pathogeny of such dysfunctions has not been studied enough, but it is obvious that if they exist, the child's development occurs on the basis of distorted perceptual information

(Bishop, Hardiman, & Barry, 2012; Kraus, 2001; Skoe, Krizman, Spitzer, & Kraus, 2013; Stefanics, 2011). Thus, disturbance of conduction and primary processing of information in the brain stem could be the reason for derivative cortical dysfunctions.

In a number of studies, the following concept of the bond of the ABR components to the auditory system has been proposed: I — the auditory nerve; II — the cochlear nucleus; III — the core of the superior olive; IV — the lateral loop; V — the lower tubercle; VI — the medial geniculate body of the thalamus (Efimov et al., 2014; Leite, 2014). Thus, the deceleration of the auditory signal conduction in the region from the olivary complex to the lower tubercle on the right turned out to be the most significant in our study.

With normal peripheral hearing, the inability of the child to effectively perceive auditory information is called Central Auditory Processing Disorder (CAPD) in the English literature. This term was adopted by the American Speech-Language-Hearing Association (ASHA) in 1996 to denote problems in one or several fields related to the brain's processing of information perceived by the ears: localization of the sound source, differentiation of sounds, recognition of the sequences of sound stimuli, and speed of processing of the auditory information. CAPD may be combined with other dysfunctions, such as language development disorders and specific learning disabilities. The latter were pronounced in children with speech disorders and autism (Moore & Hunter, 2013; Vandewalle, Boets, Ghesquière, & Zink, 2012).

Development of the language function in the child depends, first of all, on the coordinated interaction of the afferent and efferent systems, beginning from the auditory nuclei of the lower part of the brain stem and ending with the cerebral cortex (Billiet, 2014); these are regions in which the vestibular and auditory systems interact closely.

According to L.A. Orbeli (1961), the cerebral cortex has no direct connections either to the muscles or to sense organs, and it perceives and transmits signals by means of the spinal cord and the stem structures of the brain. That is why the child's cognitive activity depends not only upon the cortex, but also the whole brain. With functional deficiency of the lower regions of the brain, the CNS is overloaded with "corporeal" information, and cannot fully function and develop (de Quiros & Schrager, 1978).

Our research confirmed the correlation between the subjects' nonverbal intelligence as assessed by the Raven test and the vestibular function as assessed by the cVEMP method.

It is known that the hippocampus is involved in memory. M.-B. and E. Moser (2008) detected specific neurons in the hippocampus that were called place neurons. Perceiving information from the vestibular system, those cells determine the head position and allow orientation in space, building and memorizing unique "spatial grids". Our data showed that a psychologist has additional techniques for enhancing the intelligence and speech abilities of the preschooler. During the preschool period, the brain is quite flexible. Research on the development of the vestibular apparatus and increasing the conduction efficiency of the auditory system might considerably hasten the development of speech in children with speech disorders.

Limitations

Only children with pronounced speech problems participated in our study. A larger sample is needed, including healthy children, but we found it extremely difficult to explain to the parents of those children the importance of such instrumental testing. However, this should be done in future studies.

Further research requires extension of the number of subcortical structures under study, and investigation of the relationship of the cortical and subcortical structures to the development of speech in preschoolers.

Conclusion

1. In the sample of preschool-age children (4-7 years old), severity of speech problems was not associated directly with nonverbal intelligence.
2. All the children with pronounced speech problems had conduction disturbances in their auditory and vestibular systems.
3. Conduction disturbances in the auditory system were directly connected with the severity of speech problems.
4. Conduction disturbances in the vestibular system were associated with lower nonverbal intelligence.

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Modeling Personality Structure Using Semantic Relationships: Is the HEXACO Honesty-Humility a Distinct Trait?

C. M. Hew D. Gill*, Elizaveta Berezina

Sunway University, Malaysia

* Corresponding author. E-mail: hewg@sunway.edu.my

Background. Although the Big Five model (BFM) of personality has been the dominant paradigm in personality research since the mid-1990s, it has recently been challenged by the HEXACO model, which contains an additional factor called Honesty-Humility. Since both these models of personality were developed using the same factor analytic techniques, there has been an ongoing but inconclusive debate about the relative merits of these competing models.

Objective. This paper assesses the robustness of the Honesty-Humility trait using a technique based on the semantic relationships between personality trait adjectives.

Design. Trait marker adjectives for the HEXACO Honesty-Humility and BFM Agreeableness and Neuroticism personality domains in the English language are translated into, and back-translated from, six Asian languages to generate lists of closely related trait terms known as schedonyms. The numbers of schedonyms found within and across the three personality domains are then compared, to determine whether the HEXACO Honesty-Humility factor is semantically distinct from the BFM traits of Agreeableness and Neuroticism.

Results. Our findings indicate that the Honesty-Humility trait domain is semantically distinct from the BFM traits of Agreeableness and Neuroticism, and therefore that there is at least one more personality trait beyond the BFM. The implications of these findings, and the potential applications of this semantically-based technique for establishing the universal structure of the human personality, are briefly discussed.

Conclusion. Our semantic analysis provides clear evidence that there is an Honesty-Humility trait domain in addition to the Agreeableness and Neuroticism traits, and therefore that HEXACO provides a better description of human personality than the BFM.

Keywords:
Big Five Model (BFM), HEXACO, Honesty-Humility (H6), Agreeableness, Neuroticism, schedonyms, lexical argument, private language argument, Asian languages, personality traits

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Introduction

Over the past two and a half decades, the "Big Five" model (BFM) of personality traits, which consists of Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience, has gained much support among researchers as a description of the fundamentals of human personality (Borghuis et al., 2017; Hodgkinson & Gill, 2015; Leutner, Ahmetoglu, Akhtar, & Chamorro-Premuzic, 2014; Shmelev, 2002). The BFM is said to have a biological basis (Power & Pluess, 2015; Trofimova, 2016), and to constitute a generalizable description of personality that is applicable across all cultures and languages (Kajonius et al., 2017; Schmitt et al., 2007). However, since its inception, the BFM has had its critics, with some suggesting the BFM may be too complex (e.g. Mitchell & Kumari, 2016; Gurven, von Rueden, Massenkoff, Kaplan, & Lero Vie, 2013; Eysenck, 1992), and even apparent advocates for the BFM arguing that it may not be complex enough (Barelds & De Raad, 2015; Cattell, 1995; Mõttus, Kandler, Bleidorn, Riemann, & McCrae, 2017; Waller, 1995).

More recently, the six-factor HEXACO model of personality, which adds the trait of Honesty-Humility to the others (Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness) (Ashton, Lee, & Boies, 2015), has begun to attract some scholarly support (Anglim, Leivens, Everton, Grant, & Marty, 2018; Strouts, Brase, & Dillon, 2017; Shu, McAbee, & Ayman, 2017).

Since the BFM and HEXACO were primarily developed by using factor analysis[1] of personality trait adjectives, much of the debate about which model is best has hinged on the various methodological decisions made by the researchers conducting the analyses. However, there are no universally agreed-upon and objective criteria for carrying out a factor analysis. Therefore, selecting the number of factors to extract, and choosing the method of factor rotation, are matters decided by each individual researcher; multiple related models can be extracted from the same dataset (Loehlin, 2013). Unsurprisingly, the lack of a common approach has led to considerable disagreement about which technique(s) may or may not be correct, the number of factors that should be extracted, and even the relatedness or orthogonality of those factors (Davies, Connelly, Ones, & Birkland, 2015; de Vries, 2011; Putilov, 2018; Wright, 2017). This, in turn, has meant that the validity of any particular personality model has become, for many, a matter of personal judgment, and led some to call for a paradigm shift in our approach to the measurement of personality (Uher, 2013).

The BFM and HEXACO were both developed within the lexical hypothesis (Galton, 1884; Saucier, & Goldberg, 1996), which proposes that important personality characteristics will be encoded in a language as a single word (De Raad & Mlačić, 2017; John, Angleitner, & Ostendorf, 1988). The factor analytic approach relies on the assumption that when participants use personality trait adjectives to rate themselves, the ratings will show some correlations because many trait adjec-

[1] Actually, most personality researchers have used principal components analysis (PCA) instead of factor analysis, but since the latter term has become so embedded in the literature, it shall be used here. It should be noted that, although PCA is an approach that falls within the broad family of factor analytic techniques, it is subject to a set of assumptions and constraints that differ in some significant respects from general factor analysis; by far the most accessible introduction to the field is Paul Kline's (1993; 2014) *An Easy Guide to Factor Analysis*. London: Routledge.

tives will be synonyms–i.e., descriptions of closely related aspects of personality which are semantically and psychologically related (Saucier & Goldberg, 1996).

However, the lexical argument pre-dates Wittgenstein's (1953; 2009) private language argument (PLA), which asserts that language can only exist in the public domain where semantic meanings are agreed upon between language users (Leontiev, 2017; Vygotsky, 1987). If we accept that any trait adjective is a publicly agreed-upon term for an aspect of personality, then why would language users generate many words that were repetitious synonyms? Personality corpora are extensive and contain many distinct trait adjectives (e.g. Chandler, 2018; Litvinova & Ryzhkova, 2018), so surely it is more logical to conclude that each trait adjective describes a unique aspect of the personality, and although it may be true that many trait adjectives are related, they are not exact synonyms, but rather schedonyms – descriptive terms that are close but not identical in meaning.

So, for example, trait adjectives that are often considered to be synonyms–such as *friendly*, *gregarious*, *likeable*, *outgoing*, *pleasant,* and *sociable*–are not actually terms that can be used interchangeably. They are in fact schedonyms, which only exist as trait adjectives because they make meaningful and publicly agreed-upon distinctions among different aspects of human personality. Thus, any trait domain should contain groups of schedonyms, some of which are very close in meaning, and some of which may not be particularly close in meaning.

For example, people who are *friendly* may also be *sociable*, *outgoing,* and *pleasant*, but it is not necessarily the case that people who are *outgoing* are always *pleasant* or *friendly.* This is why these distinct trait adjectives exist as schedonyms, which are closely related but not semantically identical. Similarly, the trait adjectives *dutiful*, *honest*, *honorable,* and *responsible* may be close in meaning to each other, but they are not semantically identical, and they are clearly semantically distant from the trait adjectives *sociable*, *outgoing,* and *pleasant*.

Clusters of schedonyms have developed over thousands of years, as millions of language users have developed agreed-upon meanings to describe close but distinct aspects of human personality. Even though human languages have progressively differentiated from their common origins (Velichkovsky & Rumbaugh, 2013), if the structure of the human personality is universal, then the trait adjectives found in one language should have analogues in other languages, and these trait adjectives should be related in broadly consistent ways. This means that when a trait adjective is translated from a first or meta-language, into a second target language, and then back-translated to the meta-language, the result should be the same trait adjective in the original meta-language, and a cluster of its closest related trait adjective schedonyms.

Schedonyms act as semantic tags, with their clusters showing close semantic, and hence psychological, relationships. Conversely, trait adjectives from distinct personality trait domains should share very few, or even zero, schedonyms. So, for example, when the target trait adjective *friendly* is translated and back-translated, it should yield the adjective *friendly,* and might also yield schedonyms such as *gregarious*, *likeable*, *outgoing*, *pleasant,* and *sociable* in nearly all languages, but the list of schedonyms might not be identical across different languages. Then, when the trait adjective *outgoing* is translated and back-translated, it might yield the schedonyms *gregarious* and *sociable* in all languages, and the adjectives *likeable* and *pleasant* in some languages, while in a few languages, it might yield *demonstrative* and *expansive*. When *expansive* is back-translated, it might yield *generous* and *liberal* in all languages, with *outgoing* and *friendly* in some languages.

By translating and back-translating trait adjectives through multiple languages, it should be possible to assess the relatedness of trait adjectives, and the strength of their semantic and psychological relationships, based upon the number of schedonyms shared between them. This means that counting the number of schedonyms shared between individual trait adjectives could offer a viable alternative to factor-analysis as a means of assessing the content and robustness of personality domains.

The HEXACO model is effectively composed of the BFM plus the Honesty-Humility trait (H6), which is derived using adjectives (and therefore factor-analytic variance) that other researchers would consider to be part of the BFM Agreeableness and Neuroticism trait domains (Ashton, Lee, & de Vries, 2014). If H6 is independent of the Agreeableness and Neuroticism domains, then it would be expected that H6 trait marker adjectives would share very few or no schedonyms with trait marker adjectives from the two BFM traits. The present study will use schedonyms to investigate the extent to which the putative H6 trait domain is related to, or distinct from, the BFM's Agreeableness and Neuroticism traits.

Method

Using the trait adjective lists provided by Saucier & Goldberg (1996) and Ashton et al. (2015), we identified 10 marker adjectives for each of the trait domains for the BFM's Agreeableness and Neuroticism, and HEXACO's H6, as shown in *Table 1*.

Table 1

Trait marker adjectives representative of H6, Agreeableness, and Neuroticism

H6 Trait Adjectives from Ashton et al. (2015)	**Agreeableness Trait Adjectives from Saucier & Goldberg (1996)**	**Neuroticism Trait Adjectives from Saucier & Goldberg (1996)**
sincere	sympathetic	moody
generous	kind*	touchy
honest	cooperative	temperamental
trustworthy	courteous	irritable
loyal	compassionate*	emotional
snobbish	harsh	relaxed
greedy	rude	patient
deceitful	antagonistic	brave
conceited	abusive	casual
superficial	egotistical	earthy

**Note: the trait adjectives kind and compassionate were also listed by Ashton et al. (2015) as H6 trait terms, but as this would have immediately meant a perfect match between 20% of the available trait adjectives, it was decided to select alternative adjectives as trait markers.*

The initial list did not include any privative constructed negatives — words that use the English prefixes in/un/dis to form negatives (e.g. insincere, unkind) — because 1) these terms are not independently generated trait adjectives, and 2) when they are translated into target languages, they often yield phrases beginning with не/tidak/不/wala, etc. Similarly, compound terms using a hyphen to connect two ideas (e.g. self-centered; warm-hearted) were not selected, because similar compound terms might not exist in the same form in some languages, and they could also be translated as idiomatic phrases unique to the language in question.

Since the H6 trait has been found in several factor analytic studies conducted in Asia (De Raad & Mlacic, 2017; Fan, Zhichen, Beibei, & Jixia, 2015; Han, Seok, & Kim, 2017; Kawamoto, 2016), the present study used English as the first or meta-language, with six South East Asian languages from three language families as target languages, to yield a broad spread of trait adjectives from back-translation, and to boost generalizability.

Table 2

Target languages and language families used for translating the trait marker adjectives

Austronesian		**Austroasiatic (Mon-Khmer)**		**Tai-Kadai (Zhuang-Tai)**	
Indonesian	Filipino	Khmer	Vietnamese	Lao	Thai

The initial trait adjectives were translated from English into the target languages using 20 public domain bilingual dictionaries; then the resulting adjectives were back-translated into English to generate lists of schedonyms for each of the trait marker adjectives. Again, any compound terms that were yielded during translation (e.g. *home-felt*, *pure-minded*, *fair-spoken*) were eliminated. As an example, the trait adjective *sincere,* when translated into Bahasa Indonesia, yielded the adjective *tulus,* which, when back-translated, yielded *sincere* and 12 more adjectives, including *candid*, *honest*, *truthful,* and *upright*; nine compound terms, including *heart-whole*, *single-eyed,* and *true-blue,* were excluded from further analysis. When *honest* was translated into Thai, it yielded the term sụ̄̀xs̄ạty̒ (ซื่อสัตย์), that, when back-translated, yielded *honest* and 40 more adjectives, of which four were excluded and 36 retained, including *candid*, *sincere*, *truthful,* and *upright.*

Calculation of Intra-trait and Inter-trait Schedonyms

Following from the above, we can see that within the putative H6 personality domain, the initial trait adjective *sincere,* when translated into and back from Bahasa Indonesia, yielded the four adjectives *candid*, *honest*, *truthful,* and *upright,* and that the Thai translation of *honest* yielded *candid*, *sincere*, *truthful,* and *upright*. Each of these terms was therefore counted as one intra-trait schedonym within H6 for each initial trait adjective, making a total of four per initial adjective, and eight in total. However, note that the direct back-translations of *sincere* to *sincere* in Bahasa Indonesia, and *honest* to *honest* in Thai, were not counted as intra-trait schedonyms, and that no direct back-translations of the initial adjective terms were counted for any of the target languages, as this would have artificially inflated the apparent number of intra-trait schedonyms.

The inter-trait schedonyms shared between the personality trait domains were counted in the same way. The back-translations of the H6 initial adjective *generous* in Thai, and the Agreeableness initial adjective *kind* in Filipino, both yielded *considerate*, and this was counted as one schedonym for each initial trait adjective, for a total count of two inter-trait schedonyms. When an H6 initial adjective yielded a schedonym the same as an Agreeableness initial adjective, or vice versa, the schedonym was counted as an inter-trait one, to capture the relationship between initial trait adjectives from different personality domains.

Results and Discussion

The numbers of trait adjectives generated following the translation and back-translation of the initial trait marker adjectives are shown in *Tables 3, 4* and *5*.

Table 3

Number of schedonyms generated for H6 trait adjectives by translation into and back-translation from the six Asian languages

H6 Initial Trait Adjectives	Indonesian	Filipino	Khmer	Vietnamese	Lao	Thai	Totals
sincere	58	25	40	24	37	72	256
generous	18	14	15	11	11	33	102
honest	73	127	58	28	37	121	444
trustworthy	31	25	67	18	15	34	190
loyal	36	132	36	30	40	59	333
snobbish	12	10	17	1	20	8	68
greedy	5	3	3	8	14	12	45
deceitful	24	21	22	18	9	24	118
conceited	51	28	28	39	21	39	206
superficial	6	6	8	3	0	15	38
TOTALS	314	391	294	180	204	417	1800

The H6 adjectives yielded a reasonable number of adjectives, with Bahasa Indonesia, Filipino, and Thai having the largest number of schedonyms, although it should be noted that Lao yielded comparatively few schedonyms because few dictionary resources were available. The trait adjective with the largest number of schedonyms was *honest,* followed by *loyal* and *sincere*, which might be considered as anchor trait adjectives for the Honesty pole of the H6 personality domain.

Table 4

Number of schedonyms generated for Agreeableness trait adjectives by translation into and back-translation from the six Asian languages

Agreeableness Initial Trait Adjectives	Indonesian	Filipino	Khmer	Vietnamese	Lao	Thai	Totals
sympathetic	24	21	7	19	6	37	114
kind	76	86	53	19	18	67	319
cooperative	2	12	1	2	1	1	19
courteous	83	42	13	55	12	61	266
compassionate	36	31	9	19	7	83	185
harsh	46	39	21	53	7	49	215
rude	120	72	22	67	16	90	387
antagonistic	0	1	1	1	1	2	6
abusive	42	15	9	48	9	105	228
egotistical	6	4	4	4	0	10	28
TOTALS	435	323	140	287	77	505	1767

Table 5

Number of schedonyms generated for Neuroticism trait adjectives by translation into and back-translation from the six Asian languages

Neuroticism Initial Trait Adjectives	Indonesian	Filipino	Khmer	Vietnamese	Lao	Thai	Totals
moody	28	16	7	24	5	27	107
touchy	37	24	0	23	1	4	89
temperamental	4	15	3	9	3	27	61
irritable	50	36	2	25	9	18	140
emotional	10	11	3	10	3	3	40
relaxed	6	1	1	3	0	7	18
patient	7	3	0	7	2	6	25
brave	42	45	22	25	1	42	177
casual	16	3	6	7	3	5	40
earthy	46	11	22	1	5	49	134
TOTALS	246	165	66	134	32	188	831

Agreeableness yielded fewer schedonyms than H6, but with Bahasa Indonesia, Filipino, and Thai again yielding the most schedonyms. The adjective *rude* had most schedonyms, followed by *kind*, but the adjectives *antagonistic* and *egotistical* generated relatively few back-translations. This may have been because *antagonistic* and *egotistical* are relatively uncommon words in English so that few translations have been yet been generated in the target languages. The trait adjective *co-operative* also generated few schedonyms, and this was partially because the term was commonly translated as a noun meaning "farm co-operative" in several of the target languages.

The Neuroticism trait adjectives had the fewest schedonyms, although again, the proportions of schedonyms from each target language were broadly consistent with those for the other two personality domains. The trait adjectives with the greatest number of schedonyms were *earthy* and *brave,* but, in comparison, there were few schedonyms for *temperamental*, *emotional,* and *relaxed*.

Comparison of Intra-trait vs Inter-trait Schedonyms

As explained above, trait adjectives from within the same trait should have a relatively high count of intra-trait schedonyms, and more intra-trait schedonyms than inter-trait schedonyms shared with unrelated trait domains. Thus, the total number of intra-trait schedonyms should be significantly higher than the number of inter-trait schedonyms, and this appeared to be the case when the intra-trait and inter-trait schedonym counts were compared as shown in *Tables 6, 7,* and *8* below.

Table 6

Number of intra-trait and inter-trait schedonyms for the H6 trait adjectives across the six Asian languages

H6 Trait Adjectives	H6 intra-trait schedonyms	Agreeableness inter-trait schedonyms	Neuroticism inter-trait schedonyms
sincere	256	13	1
Generous	102	225	11
Honest	444	53	5
trustworthy	190	12	0
loyal	333	12	1
snobbish	68	24	1
greedy	45	8	0
deceitful	118	3	2
conceited	206	64	0
superficial	38	5	4
TOTALS	1800	419	25

The figures in *Table 6* show that the H6 positive-pole trait adjectives *sincere*, *honest*, *trustworthy,* and *loyal* produced a relatively large number of intra-trait schedonyms but few inter-trait schedonyms, exactly the pattern which would be expected if these terms are at the core of a distinct personality domain. Conversely, *generous* yielded a comparatively lower number of intra-trait schedonyms, but higher numbers of inter-trait schedonyms with the Agreeableness domain, suggesting that it might be drawn from the Agreeableness rather than the H6 personality domain.

Among the H6 negative-pole adjectives, *snobbish* and *conceited* had a moderate number of intra-trait schedonyms, but *greedy*, *deceitful,* and *superficial* had very few schedonyms within the H6 domain, or across the other two domains. This suggests that the negative pole of H6 is not particularly well-defined by these five trait adjectives. Indeed, since *deceitful* is an antonym for *sincere*, *honest,* and *trustworthy*, yet shares few schedonyms with the other four adjectives, it seems probable that *snobbish*, *conceited, greedy*, and *superficial* do not capture the negative pole of the Honesty aspect of H6. However, the fact that *snobbish* and *conceited* share a fair number intra-trait schedonyms, yet are unrelated to Agreeableness or Neuroticism, suggests they may capture the negative pole of the Humility aspect of H6.

Table 7

Number of intra-trait and inter-trait schedonyms for the Agreeableness trait adjectives across the six Asian languages

Agreeableness Trait Adjectives	**Agreeableness intra-trait schedonyms**	**H6 inter-trait schedonyms**	**Neuroticism inter-trait schedonyms**
sympathetic	114	43	5
kind	319	25	3
cooperative	19	0	0
courteous	266	14	19
compassionate	185	4	4
harsh	215	7	109
rude	387	14	263
antagonistic	6	0	0
abusive	228	6	109
egotistical	28	79	0
TOTALS	1767	192	512

The Agreeableness adjectives (See *Table 7*) had many intra-trait schedonyms, which suggested a high degree of semantic relatedness, and that most of the adjectives came from the same personality domain. The Agreeableness antonyms *antagonistic* and *egotistical* shared few schedonyms with other Agreeableness trait adjectives, and *egotistical* appeared to be more closely related to the H6 domain, possibly because it may be part of the negative pole of the Humility aspect of H6.

Table 8

Number of intra-trait and inter-trait schedonyms for the Neuroticism trait adjectives across the six Asian languages

Neuroticism Trait Adjectives	**Neuroticism intra-trait schedonyms**	**H6 inter-trait schedonyms**	**Agreeableness inter-trait schedonyms**
moody	107	0	28
touchy	89	3	25
temperamental	61	0	14
irritable	140	1	38
emotional	40	0	7
relaxed	18	0	1
patient	25	8	15
brave	177	3	42
casual	40	5	29
earthy	134	5	342
TOTALS	831	25	541

The Neuroticism trait adjectives yielded fewer intra-trait schedonyms than the other domains, although *moody*, *touchy*, *temperamental,* and *irritable* did show some modest counts and ratios. There were comparatively few schedonyms at the Emotional Stability pole of this domain, with the adjectives *patient* and *relaxed* having very few intra-trait schedonyms, despite the fact that they are generally associated with the positive pole of this domain. This may have been because the trait adjectives *brave*, *casual,* and *earthy* are actually drawn from other domains; for example, *brave* has been identified in other studies as part of the positive pole of Extraversion, and *casual* as part of the negative pole of Conscientiousness (e.g. Gill & Hodgkinson, 2007). The figures in *Table 8* suggest that *earthy* may be more closely associated with the Agreeableness domain.

The figures presented in *Tables 6, 7*, and *8* showed that many of the trait marker adjectives in each of the three personality domains had more intra-trait schedonyms than inter-trait schedonyms, suggesting that H6, Agreeableness, and Neuroticism are semantically distinct. In order to investigate whether or not these different patterns of semantic relationships were significantly different, the numbers of intra-trait and inter-trait schedonyms were compared across the three trait domains using the Kruskal-Wallis test.

There is a significant difference in the number of intra-trait schedonyms shared within the H6 domain, as compared with the number of inter-trait schedonyms shared between the H6 domain and the Agreeableness and Neuroticism domains;

($H(2)=21.83$, $p<0.01$) with a mean rank of 24.40 for H6 intra-trait schedonyms, a mean rank of 16.05 for inter-trait schedonyms between H6 and Agreeableness, and a mean rank of 6.04 for inter-trait schedonyms between H6 and Neuroticism.

There is also a significant difference in the number of intra-trait schedonyms shared within the Agreeableness domain, compared with the number of inter-trait schedonyms shared between the Agreeableness domain, and the H6 and Neuroticism domains; ($H(2)=10.66$, $p<0.01$) with a mean rank of 22.90 intra-trait schedonyms for Agreeableness, a mean rank of 11.90 for inter-trait schedonyms between Agreeableness and H6, and a mean rank of 11.70 for inter-trait schedonyms between Agreeableness and Neuroticism.

Lastly, there are significant differences in the number of intra-trait schedonyms shared within the Neuroticism domain, compared with the numbers of inter-trait schedonyms shared between the Neuroticism domain and the H6 and Agreeableness domains ($H(2)=19.59$, $p<0.01$) with a mean rank of 23.35 for Neuroticism intra-trait schedonyms, a mean rank of 6.15 for inter-trait schedonyms between Neuroticism and H6, and a mean rank of 17.00 for inter-trait schedonyms between Neuroticism and Agreeableness.

Overall, these findings show that the H6, Agreeableness, and Neuroticism trait marker adjectives have significantly more semantic relationships within their respective personality domains than they share across other personality domains, suggesting that these traits are robust and semantically distinct personality trait domains.

General Discussion

The present research was a pilot study designed to investigate the semantic robustness of the H6 personality trait proposed by Ashton et al. (2015), which used a novel approach that could serve as an alternative to factor-analysis, and a means of confirming personality domains using semantic relationships that have evolved over millenia.

The results showed that H6 is semantically robust and semantically distinct from Neuroticism and Agreeableness, allowing us to tentatively conclude that the HEXACO model of personality, including the H6 Honesty-Humility factor, offers a more comprehensive description of the human personality than the five traits of the BFM. Furthermore, the fact that these semantic relationships were established using trait adjective schedonyms from six South East Asian languages and three major language groups, suggests that the findings of the present study may be generalizable, and that the H6 Honesty-Humility trait domain is likely to be semantically robust in other languages.

However, we should also note that the H6 marker adjectives selected for the present study are mostly representative of the H6 positive Honesty pole and negative Humility pole. Future research needs to include more adjectives representative of the negative Honesty and positive Humility poles, in order to demonstrate that H6 is indeed semantically distinct, and also that H6 is itself a unitary personality domain.

Although it was apparent that some of the trait adjectives within each personality domain had relatively few semantic relationships with other adjectives in the same assumed domain, this may have been because the comparatively small number of marker trait adjectives used meant that the full breadth of semantic relationships was not sampled. However, it is also possible that some of the initial trait marker adjectives were not actually drawn from the trait domains to which they were factor-analytically allocated, and instead rightly belong in other personality domains; the most obvious examples were the adjectives *brave* and *casual*. Indeed, if *brave* and *casual* are actually trait markers for Extraversion and Conscientiousness, then this would explain why they shared so few schedonyms with any of the three factors being investigated in the present study.

Any personality domain should be semantically defined both by the trait adjectives it includes, and those it does not, so ultimately it may be possible to apply this semantically-based technique to much larger samples of trait adjectives. This would allow us to establish the robustness and semantic integrity of any given personality trait domain, as well as the number of personality domains that are present in any collection of trait adjectives. Such an approach might also make it possible to adopt an iterative approach to personality domain specification, by assessing how well individual trait adjectives fit into different domains using the comparative number of intra-trait and inter-trait adjective schedonyms, although clearly this would require much larger initial item pools in order to achieve the statistical power necessary to allocate adjectives accurately.

Limitations

We must acknowledge that the present study used a limited sample of core trait adjectives drawn from what might be considered "master-lists" for the BFM and HEXACO. This means that further verification is required using a larger pool of trait adjectives. Furthermore, despite the fact that Ashton et al. (2015) identify Agreeableness and Neuroticism as the hierarchical "parents" of H6 Honesty-Humility, it is possible that H6 may not be semantically distinct from Extraversion, Conscientiousness, and Openness. Thus a future study including trait adjectives from all the BFM personality domains alongside H6 Honesty-Humility is clearly required. This may also serve to establish whether *brave* and *casual* are part of the Neuroticism trait or other domains, as well as helping to locate the appropriate personality domains for the other trait adjectives which had low numbers of intra-trait and inter-trait schedonyms in the present study.

Another objective of this research was to try out a novel alternative to factor-analysis for assessing the validity of personality trait domains by using semantic relationships. The findings reported above lend some credence to the contention that using translations and back-translations of trait adjectives to generate lists of semantically close personality terms, or schedonyms, may make it possible to map personality trait domains and the boundaries between them using the lexical relationships and distinctions that have evolved in natural language.

Even though the present study was modest in scale, and the techniques applied could be further refined by increasing the initial trait adjective pool, the languages used for translation, and the number of sources used for translation, the logic of the approach seems sound. Sampling more trait adjectives across more languages would increase the number of possible comparisons between groups of trait adjectives, and the power of the statistical analyses that could be conducted. This would then allow iterative studies to allocate trait adjectives to the correct personality domains, thus making truly valid global comparisons which will help us establish the shape of the universal domains of human personality, as well as those aspects of personality that may be culturally specific. Establishing which are the universal domains, and which the cultural specificities of human personality, must surely be the ultimate goal of personality research, and a technique based on semantic relationships may overcome some of the limitations of factor-analysis to independently validate or challenge the BFM.

Conclusion

In conclusion, this brief paper suggests that the H6 Honesty-Humility domain is semantically distinct from Agreeableness and Neuroticism, and therefore that HEXACO provides a better description of the human personality than the BFM. Hopefully, by proposing a new semantically based technique for establishing the structure of human personality, this paper represents both a minor milestone, and a modest map, for the greater journey of discovery ahead.

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The Relationship Between Executive Functions and Language Competences in Middle School Children

Boris B. Velichkovsky[a,*], Irina N. Bondarenko[b], Varvara I. Morosanova[b]

[a] *Moscow State University, Moscow, Russia*

[b] *Psychological Institute of the Russian Academy of Education, Moscow, Russia*

[*] Corresponding author. E-mail: velitchk@mail.ru

Background. Mastering a first language at school is mediated by the regulatory abilities of pupils. An open question is how the executive functions implementing conscious self-regulation are related to language competences.

Objective. To study the relationship between basic executive functions (switching, inhibition, working memory updating, and error correction) and language competences.

Design. A sample of 104 Russian middle school children (aged 13–15 years) performed three cognitive tasks assessing basic executive functions and two tasks assessing language competences in the areas of punctuation, spelling, morphology, syntax, semantics, vocabulary, and style.

Results. *Inhibition* was mostly related to punctuation, spelling, and morphology competences and was most important in the first competences task, requiring the recognition of errors. *Switching* was mostly related to the competences in syntax, reflecting the importance of switching attention between alternative syntactic structures. *Working memory updating* was the most important executive function related to language competences, with a heavy focus on higher-level lexical, semantic, and stylistic competences. The role of updating was especially important in the second competences task, which required generation of well-formed sentences. *Error correction* was mostly relevant for the recognition of language errors.

Conclusion. While inhibition and switching affect aspects of constructing the surface form of a sentence, working memory is preferentially related to the construction of semantically appropriate sentences. Error monitoring and correction are generally related to the recognition of language errors. Conscious self-regulation and its cognitive mechanisms are systematically related to the development of native language competences in middle school.

Keywords: conscious self-regulation, executive functions, native language learning, language competences, secondary school

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Introduction

The problem of how a first language is mastered at school is important both theoretically and practically. The success of learning at school (learning languages in particular) may heavily depend on pupils' self-regulatory mechanisms. The relevance of studying how conscious self-regulation (SR) is related to learning success is confirmed by a large number of researches (Baumeister & Vohs, 2004; Cascallar, Boekaerts, & Costigan, 2006; Morosanova, Fomina, & Bondarenko, 2015; Zimmerman & Schunk, 2001). Morosanova, Fomina, and Bondarenko (2015) differentiate between the regulatory-personal and cognitive levels of conscious SR. The regulatory-personal level consists of personality traits that help to achieve goals. The cognitive level is represented by processes of activity planning, modeling of situational conditions, action programming, and result evaluation. The cognitive level of SR may be implemented through executive functions (EFs)—a set of meta-cognitive functions indispensable for organizing goal-directed activities in complex dynamic contexts (Diamond, 2013; Miyake et al., 2000). The purpose of the present study is to analyze the relationship between EFs and language competences in a sample of Russian middle school children.

Executive functions. Studies have demonstrated the link between EFs and effective SR of different activities, including academic learning (Hofmann, Schmeichel, & Baddeley, 2012; Welsh & Peterson, 2014). Miyake et al. (2000) distinguished among three "basic" EFs: switching, inhibition, and working memory updating. The switching function is related to cognitive flexibility and provides for flexible transition between tasks. Such transitions are mediated by goal changes and attention switches. Inhibition is a complex system of functions associated with a voluntary decrease in the activation of mental representations and motor responses not relevant for solving the task at hand. Inhibition plays an important role in the organization of purposeful behavior and self-control. Working memory updating is associated with the storage and processing of information necessary to solve a task. Working memory updating may play an important role in the planning of activities and in the storage of action plans and situational mental models. In addition to these basic EFs, the error monitoring and correction EF associated with ensuring the quality of cognitive activity is also of great importance for goal achievement (Dutilh et al., 2012).

Language competences. The concept of language competences (LCs) has long been a topical issue in the field of teaching both native and foreign languages. The LC concept is associated with the understanding of a language as a system and with the acquisition of language norms (Bozhovich, 2016; Kecskes, Sanders, & Pomerantz, 2018). The assessment of LCs is a complex problem. Average school marks and exam scores give only very general information about a student's LCs. In this study, we rely on Bozhovich's (2016) approach to LCs diagnostics, which is widely used in Russia.

Relationships between EF and LC. Researchers have often suggested a relationship between EFs and language (Marslen-Wilson & Tyler, 2007; Veraksa, Bukhalenkova, & Kovyazina, 2018). Studies on cognitive factors of language learning (e.g., Gooch et al., 2016) suggested that EFs are related to native and foreign language learning at school. However, a recent Russian study on the contribution of EF to native language learning in school (Verbitskaya, Malykh, Zynchenko, & Tikhomirova, 2015) failed to find a link between an EF (working memory) and language exam grades. In any case, specific links between EFs and different LCs (lexical, syntactic, etc.) have not been sufficiently investigated yet.

Method

Hypotheses. We hypothesized the existence of significant relationships between EFs and LCs characterizing middle school pupils' success in learning the Russian language. We also assumed that there is a specificity of regulatory predictors of individual LCs (orthography, punctuation, lexical features, etc.).

Sample. The study was performed on a sample of middle school students from Moscow and Moscow Region aged 13–16 years: seventh graders (N = 53, mean age 13 ± 0.5 years) and ninth graders (N = 51, mean age 15 ± 0.5 years). Gender was distributed almost evenly within the sample (50.3% female).

EF measures. We used three standard tasks for the assessment of basic EFs (Miyake et al., 2000). To assess *inhibition* we used the Eriksen Flanker task. The stimuli are five horizontally arranged black arrows presented against a white background in two conditions: a congruent condition (>>>>>, <<<<<) and an incongruent condition (>><>>, <<><<). The subjects' task is to attend to the arrow in the middle and to indicate its direction by pressing the corresponding key ("z" for left and "/" for right). A training session comprised of 36 trials is included. The main series contains four blocks with 36 unique trials in each. The maximum response time is 1,500 ms. The response to stimulus interval is fixed at 1,000 ms. Four response parameters are registered: average reaction time, percentage of correct answers, and the difference in reaction time and accuracy between the congruent and noncongruent trials (the interference effect).

To assess *switching,* we used the Letter-Number task with predictable task changes. A white screen is shown divided into four quadrants. In each quadrant, a pair of symbols is presented clockwise, starting with the upper left quadrant: a digit and a letter. The subjects' task is to determine whether the digit is even or odd if the characters are located in one of the upper quadrants, and whether the letter is a consonant or a vowel if the symbols appear in one of the lower quadrants. The answer is given by pressing a key ("z" for odd digits and vowel letters and "/" for even digits and consonant letters). The training series consists of 24 letter-digit pairs. The main series consists of 128 trials. The stimuli remain on the screen until the response is given. The response to stimulus interval is 500 ms. Six response parameters are registered: average reaction time and accuracy, repetition trials' reaction times and accuracy, switching trials' reaction times and accuracy, and two switch costs indicating switching efficiency (the differences in reaction time and accuracy between switching and repetition trials).

To evaluate *working memory updating,* we used the N-Back task. The digits from 1 to 8 are presented in a pseudo-random order. The task of the subject is to answer quickly and correctly whether the currently presented digit coincides with the digit presented two positions before (2-back). The training series contains 32 trials, and the two main series each contain 48 trials. Each figure appears six times in each series (four times in the training series), once as a target. Stimulus presentation time is 500 ms. The inter-stimulus interval is 2,000 ms. The answer is given by pressing a key ("/" for yes or "z" for no). Average reaction time, accuracy, and reaction times and counts for different response types (hits, correct rejections, false alarms, and misses) are recorded.

To assess *error correction,* we computed the post-error slowing (PES) effect. PES (Dutilh et al., 2012) is the effect of trials after an incorrect trial exhibiting larger reaction times. The PES effect is associated with the activity of the conscious error monitoring and correction system within the anterior cingulate cortex (Botvinick, Braver, Barch, Carter, & Cohen, 2001). We computed PES by subtracting the average reaction time from the average reaction time in the post-error trials in each EF task.

LC measures. We used two tasks for LC diagnostics (Bozhovich, 2016). Task 1 consists of 20 sentences presented in printed form. It includes eight types of errors: orthographical (spelling errors), punctuation (a sign at the end of a sentence), morphological (incorrect word forms), lexical (violation of the norms of word usage), syntactical (violation of the connection between words), semantic-syntactical (use of structure that does not correspond to the content of sentence), semantic (the content of the sentence does not correspond to the non-linguistic reality), and stylistic errors (inadequate choice of words, sentence structure, word order, word combinations, etc.). Each sentence contains one error. Each type of error is contained in two sentences. There is no more than one error in a sentence, so there are 16 sentences with errors and four sentences without errors, serving as distracters. The subject's task is to find errors in the sentences and to mark them on the sheet.

Task 2 requires active transformation of language elements. Task 2 also consists of 20 sentences; 16 sentences contain the eight types of errors from Task 1. Four sentences do not contain errors, similar to Task 1. The subject's task is to copy the sentence to the answer sheet if there are no errors; if there is an error, the subject should correctly rewrite the sentence. No time limits were imposed in Tasks 1 and 2. The collected data are compared with an answer key and error omissions are evaluated according to the "cost" of an error: orthographical and punctuation errors add three points to the LC score; morphological, syntactical, syntactic-semantic, semantic, lexical, and stylistic errors add two points; and "false alarms" (wrongly recognized errors) add one point. Errors made in the rewritten sentences are indicated as an additional measure, according to the type of error. Overall LC scores (computed separately for Task 1 and 2) range between zero and 60. Within each LC task, a separate score is computed for each competence (given by error type). A higher LC score is indicative of less competent language use.

Procedure. The pupils performed tasks for the assessment of LC in the classroom. Computerized tasks for EF assessment were performed in the computer lab on another day.

Results

To test the hypothesis about the relationship between EFs and LCs, we conducted a correlation analysis (Pearson's r) of all studied variables for Task 1 (Table 1) and Task 2 (Table 2). In the tables, only EF measures with significant correlations with LCs are shown.

EF-LC relationship (Task 1). For *switching,* the only significant correlation is found for syntax errors. The lower the switch cost (the more effectively a child switches between tasks), the more syntax errors occur. This is contrary to intuition, and we would speak about the phenomenon of "excessive cognitive control". Excessive cognitive flexibility means excessive distractibility, and excessive attention switching during the analysis of syntactically complex constructions may provoke syntax errors. This suggests a very complex relationship between EFs and LCs in children, in whom EFs are not fully developed until the age of about 18–20 years (Luna, 2009).

Table 1

Correlations Among EF and LC Measures in Task 1

	Errors								
	O	**P**	**M**	**SS**	**Syn**	**St**	**L**	**S**	**OS**
Switching									
Switch cost (errors)					−.22*				
Inhibition									
Accuracy (all trials)					−.20*	.19*			
Accuracy (congruent trials)	.17				−.19*				
Accuracy (incongruent trials)					−.23*	.20*			
Interference strength (errors)					.30***	.17			
Updating									
Reaction time	*.17*					.25**			
Reaction time (hits)	.23*					.22*		.17	.18
Reaction time (false alarms)	.25**								
Reaction time (correct rejections)						.23*			
Accuracy (correct rejections)						.26**	*.18*		

Notes. *O = orthographical errors. P = punctuation errors. M = morphological errors. SS = semantic-syntactical errors. Syn = syntactical errors. St = stylistic errors. L = lexical errors. S = semantic errors. OS = overall LC score. Italicized numbers denote a tendency. *p < .05. **p < .01. ***p < .001.*

The analysis of *inhibition* found relationships with syntax and style errors. The lower the inhibition accuracy as well as the accuracy in congruent and incongruent trials, the more syntax errors are missed by the subjects. In the same vein, we found a clear direct relationship between interference strength and syntactic and stylistic errors. Less effective interference inhibition is associated with more syntactic and stylistic errors being omitted. This suggests an important role of inhibition associatively activated, but incorrect syntactic and stylistic constructions.

The most relationships with LCs in Task 1 were found for *updating*. Slower reactions in the updating task were associated with higher probability of missing spelling errors. This may be related to less effective transformation of a word's sound form into graphic form in working memory. Low speed and accuracy in the updating task are associated with worse processing of stylistic errors. This may be related to deficits in the construction of sentence surface structure in working memory. A similar mechanism may lead to the emergence of the relationship between inefficient updating and worse processing of lexical and semantic errors (related to the storage and processing of situational mental models in working memory). In general, in the relatively simple Task 1 which may mostly be solved by the application of highly automatized perceptual and memory routines, problems related to inefficient EF emerge mainly during the processing of high-level errors. This is because for high-level syntactic, semantic, or stylistic errors, the role of constructing an inner plan of the sentence in working memory is especially important. It is thus not surprising that updating demonstrates the only significant correlation with LC overall score in Task 1.

Table 2

Correlations Among EF and LC Measures in Task 2

	Errors in Task 2								
	O	**P**	**M**	**SS**	**Syn**	**St**	**L**	**S**	**OS**
Switching									
RT								.29***	
RT (repeat trials)								.25**	
RT (switch trials)		.19*						.29***	
Switch cost (RT)		.22*						.25**	
Post-error slowing				.24*			.22*		*.18*
Inhibition									
Accuracy (congruent trials)					-.20*				
Accuracy (incongruent trials)			-.21*						
Interference strength (errors)			.24**						
Updating									
RT				.24*					
Accuracy		-*.18*	-.21*					-.18	
RT (hits)				.25**					
RT (correct rejections)				.22*					
Number (false alarms)							*.18*		
Number (correct rejections)						.22*			
Number (misses)								*.18*	

Notes. *O = orthographical errors. P = punctuation errors. M = morphological errors. SS = semantic-syntactical errors. Syn = syntactical errors. St = stylistic errors. L = lexical errors. S = semantic errors. OS = overall LC score. Italicized numbers denote a tendency.* $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

For *error correction*, no significant relationships with LCs were found in Task 1.

EF-LC relationship (Task 2). In Task 2, *switching* exhibited highly significant connections with LC in the areas of punctuation and semantics. Low switching efficiency (in particular, higher switching cost) led to an increase in the probability of skipping punctuation errors. This may be due to the fact that the correct use of punctuation requires parsing a sentence into syntactic-semantic units and effectively switching attention between them. Even more convincing are the links of switching efficiency with the construction of meaningful statements (semantic errors); such links were found for all indicators of reaction time in the switching task, as well as for switching costs.

For *inhibition,* a clear relationship with LCs was found in the areas of morphology and syntax. This relationship may occur because the choice of the correct word form for use in the generated sentence is determined by the need to suppress alternative forms of the same word. Such an analysis suggests that generation of the sentence structure includes a two-step process of activating lexical units with all their word forms and choosing a morphologically adequate one (extending the classical two-stage model of lexical access, Garret, 1980). A relationship between inhibition effectiveness and syntax errors has also been found. Actually, inhibition is the only EF related to syntax LC (replicating the results from Task 1). This result highlights the role of inhibition as a mechanism for choosing the correct syntactic construct among many alternatives.

For *updating,* relationships were found with several LCs in Task 2 (replicating the results from Task 1). Updating accuracy was related to LCs in the areas of punctuation and morphology. For punctuation, this may be due to the need for mental decomposition of the statement into syntactic-semantic and prosodic units in working memory. For morphology competence, this may be due to the need for mental analysis of the word components. As in Task 1, relationships were found between updating effectiveness and avoiding stylistic, lexical, and semantic errors. Working memory dynamics are also closely related to avoidance of semantic-syntactic errors. These results indicate that working memory updating is systematically associated with the basic competences in understanding and generating written speech. This is especially true for the competences in constructing meaningful sentences, possibly due to the involvement of working memory in the construction of semantic representations.

For *error correction,* some relationships with LC were obtained in Task 2, unlike Task 1. Increased post-error slowing in the switching task was related to worse processing of semantic-syntactic and lexical errors. This may be due to the ineffective use of the metacognitive strategy of critical evaluation of the generated solutions, when dealing with constructing the semantic structure of a sentence.

Data reduction. To check the hypothesis about the specifics of the regulatory predictors of different LCs, we reduced the number of analyzed variables. Exploratory factor analysis revealed latent factors characterizing the basic regulatory components that may contribute to success in mastering the Russian language in middle school. To this end, we factorized all EF indicators using the method of principal components with VARIMAX rotation. Based on the Kaiser criterion (factor weights > 1), a factor solution was obtained with eight factors explaining 76% of the variance (Table 3):

The first three factors reflect the speed of performance in the three EF tasks. The first factor (12% of the variance) was named "Updating Speed" (F1). The second factor (12% of the variance) was named "Switching Speed" (F2). The third factor (11% of the variance) was named "Inhibition Speed" (F3).

Table 3

Factor Analysis for EF Measures

Indicators	Factors							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
U/RT	.942							
U/RT (CRs)	.916							
U/RT (hits)	.829							
U/RT (misses)	.697							
U/RT (FAs)	.521							
S/RT (switch)		–.989						
S/RT		–.981						
S/Cost (RT)		–.866						
S/RT(repeat)		–.797						
I/RT (incongruent)			–.985					
I/RT			–.973					
I/RT(congruent)			–.870					
I/Interference (RT)			–.491					
I/ACC (incongruent)				.954				
I/ACC				.951				
I/ACC (congruent)				.408				
I/Interference (errors)				–.888				
S/ACC					.967			
S/ACC (repeat)					.936			
S/ACC (switch)					.928			
S/PES					.334			
U/ACC						.935		
U/N (Hits)						.660		
U/N (Misses)						–.830		
U/N (CR)							.776	
U/PES							.685	
I/PES								.570
S/Cost (Errors)								.753

Notes. U = Updating. S = Switching. I = Inhibition. RT = Reaction time. ACC = Accuracy. PES = Post-error slowing. CR = Correct rejections. Cost (Errors) = Error-related switch cost.

The following three factors reflect the accuracy of performance of the EF tasks. The fourth factor (11% of the variance) characterizes the accuracy of inhibition ("Inhibition Accuracy", F4). The fifth factor (10% of the variance) consisted of switching accuracy and switching cost ("Switching Accuracy", F5). The sixth factor (9% of the variance) included indicators of the updating task accuracy ("Updating Accuracy", F6).

The last two factors were mostly related to aspects of error correction. The seventh factor (5% of the variance) included PES and the number of correct rejections in the updating task ("Error Correction 1", F7). The eighth factor (5% of the variance) included PES in the inhibition task and the accuracy-related switching cost ("Error Correction 2", F8).

Similar analyses were performed separately for LC measures for each of the two LC tasks. For Task 1, a three-factor solution was obtained (63% of the variance explained, Table 4). The first factor (37% of the variance) reflects the general command of Russian, richness of vocabulary, and the ability to apply it depending on the situation. This factor was called "Language Proficiency". The second factor (15% of the variance) includes competences in morphology, spelling, and syntax, that is, all the language components that refer to structural analysis at the levels of words, word phrases, and sentences. This factor was called "Structure Analysis". The third factor (11% of the variance) includes competences in orthography and punctuation and is associated with applying relevant formal rules studied at school. We named it "Literacy".

Table 4

Factor Analysis for LC Measures

Competencies	**Factors**		
	1	**2**	**3**
Stylistic	.835		
Lexical	.833		
Overall score	.715		
Syntax		.837	
Orthography 1		.761	
Morphological		.758	
Punctuation			.757
Orthography 2			–.554

Notes. Orthography 1 = Errors made while performing Task 1. Orthography 2 = Errors made while reproducing sentences in Task 1.

For Task 2, a four-factor solution was obtained (64% of the variance explained, Table 5). The first factor (27% of the variance) is similar to the first factor in Task 1 ("Language Proficiency"). The second factor (15% of the variance) is similar to the third factor of Task 1, as it includes punctuation and spelling errors and reflects the literacy level ("Literacy Level"). The last two factors are a split of the second ("structural") LC factor in Task 1 and reflect the ability to structurally analyze units of language. Thus, the third factor (12% of the variance) includes morphological and spelling errors — i.e., it is associated with analysis of the word structure ("Word Structure"). The fourth factor (10% of the variance) addresses the ability to make up a well-formed sentence ("Sentence Structure").

Table 5

Factor Analysis for LC Measures

Competencies	**Factors**			
	1	**2**	**3**	**4**
Stylistic	.820			
Lexical	.796			
Overall score	.750			
Punctuation 1		.767		
Punctuation 2		.721		
Orthography 1		.633		
Morphological			.844	
Orthography 2			.607	
Semantic				.854
Syntax				.589

Notes. Orthography 1, Punctuation 1 = Errors made when performing Task 2.
Orthography 2, Punctuation 2 = Errors made in reproducing sentences in Task 2.

Regression analyses. To assess the effects of EFs on LCs, a series of multiple linear regressions was carried out. The LC factors were used separately as criteria, and the EF factors as predictors. The regressions were constructed separately for LC factors obtained for Tasks 1 and 2. To control for demographic effects, gender and age were included in the regression equations. We also included the annual grade in literature to control for general reading ability and linguistic experience. Regression coefficients for significant predictors for each of the LC factors are shown in Table 6.

In Task 1, the LC factors are systematically related to the EF factors. General language proficiency was predicted by inhibition accuracy and error correction efficiency. Structural errors were predicted by switching speed and, again, error correction efficiency. Literacy was predicted by inhibition accuracy. In Task 1, in which automatic recognition processes are important, effective switching and inhibition play a special role as LC predictors. However, inhibition may be excessive, as it actually increases the number of semantic and literacy errors. A similar phenomenon of "excessive cognitive control" has already been observed above for cognitive flexibility. Also, the regression analyses of the LC factors in Task 1 demonstrate a distinct influence of error control on LC, especially in the recognition of well-formed sentences.

Table 6

Regression Analyses for EFs as Predictors of LCs

LC Tasks	Competencies	Predictors	R^2	β	SE	B	t(92)	p
Task 1	Language Proficiency	Age	.17*	–0,233	0,102	–0,215	–2,290	0,024
		F4		0,164	0,097	0,164	1,685	0,095
		F7		0,210	0,095	0,210	2,214	0,029
	Structural errors	Sex	.19*	0,224	0,098	0,341	2,292	0,024
		F2		–0,204	0,095	–0,156	–2,153	0,034
		F8		–0,176	0,097	–0,135	–1,814	0,073
	Literacy	*Sex*	.10	0,174	0,102	0,347	1,707	0,091
		F4		0,200	0,100	0,200	2,003	0,048
Task 2	Language Proficiency	Class	.20*	–0,245	0,100	–0,106	–2,449	0,016
		F1		0,162	0,098	0,070	1,659	0,101
		F2		–0,226	0,098	–0,097	–2,317	0,023
		F6		–0,178	0,098	–0,077	–1,821	0,072
	Literacy	LN	.13***	–0,391	0,096	–0,428	–4.057	0,000
	Word Structure	*F6*	.12	–0,167	0,100	–0,167	–1,675	0,097
		F7		–0,164	0,099	–0,164	–1,647	0,103
	Sentence Structure	Age	.18*	0,273	0,102	0,391	2,673	0,009
		F2		–0,267	0,099	–0,189	–2,694	0,008

*Notes. F1 = Updating Speed. F2 = Switching Speed. F4 = Inhibition Accuracy. F6 = Updating Accuracy. F7 = Error Correction 1. F8 = Error Correction 2. LN = Annual Grade in Literature. Italics denotes a tendency, *p < .05. **p < .01. ***p < .001.*

In Task 2, there are also a number of systematic relationships between LC and EF factors. Especially pronounced are the relationships between the EF factors and language proficiency. This is not surprising, since this factor includes high-level linguistic indicators associated with semantically correct organization of sentences. Semantically correct sentence construction is associated with switching efficiency and with working memory updating. The relationship of switching to these LCs has already been shown when analyzing Task 1 performance. A new result was the close link of working memory updating to the semantics-related general language proficiency LC. This connection seems to be well-founded conceptually, since working memory serves as the mental repository in which various cognitive representations are constructed and processed (Hofmann, Schmeichel, & Baddely, 2012) and should thus be involved in the construction of the semantic structure of a sentence.

Relationships with EF factors were also obtained for both structural LC factors in Task 2. For word structure, links were found with updating factors (F6 and F7), replicating the results of the correlation analysis. This relationship may be due to the analysis of word components and the application of spelling rules when using working memory. For the sentence structure factor, a relationship was found with switching efficiency. For Task 1, we also found a relationship between switching efficiency and structural LC. The association between switching and the construction of syntactically well-formed sentences may be produced by effective switching, promoting a flexible choice between alternative syntactic structures. It is also interesting that in Task 2, contrary to Task 1, the relationship between the literacy factor and inhibition disappears. This may be because during sentence production, these LCs are highly automated and are beyond the reach of conscious control. This interpretation is confirmed by the fact that the only predictor of these LC is the annual grade in literature, indirectly reflecting the level of automation of reading and writing.

Beyond the intricate relationships between EFs and LCs found above, the actual relationships between EFs and LCs can be even more complex. Here, we attempted to show relatively basic influences of EFs on the cognitive processing of linguistic representations. On a more general level, EFs and conscious SR may be related to LCs through the organization of learning-related activities via goal setting, distractor suppression, multi-tasking management, etc. This last level is what is typically studied under the label of SR influences on academic achievement. The explication of these multi-level dependences between neurocognitive variables such as EFs, conscious SR, LCs, and academic achievement in linguistic domains will certainly require larger samples and more sophisticated research designs. However, the present results support the notion that EFs play a role in attaining linguistic competency in one's native language and, by extension, that well-developed EFs advance language learning generally. This may have implications both for structuring language courses at school and for developing necessary EF skills in school children via systematic cognitive exercise (Colzato & Hommel, 2016).

Conclusion

The results allow us to draw a number of conclusions. First, the low-level LCs such as punctuation, spelling, and morphology, and competences in syntactic analysis, were linked with inhibition. For the recognition of errors (Task 1), inhibition was the leading EF. This indicates the important role of inhibiting alternative linguistic representations during analysis of sentences. Second, for switching, a relationship was found with punctuation and syntax errors, as well as with the general ability to generate meaningful statements. This indicates the important role of switching attention between linguistic units in the process of analyzing and constructing sentences. Third, LCs found the most numerous relationships with working memory updating. These can be traced for low-level LCs related to spelling and morphology, but are most pronounced for the higher-level LCs related to lexical, semantic, and stylistic errors. The special role of working memory in the analysis and construction of sentences may be related to the function of working memory as a system for storage and transformation of mental models, including sentences' semantic and syntactic structures. Fourth, error correction was also associated with LC, especially during automatic error recognition (Task 1). Overall, the results indicate that the cognitive mechanisms of conscious SR are systematically related to the mastering of one's native language in middle school.

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Luria's Approach to the Restoration of Speech in Aphasia and the International Classification of Functioning, Disability and Health (ICFDH)

Maria E. Baulina[a,c], Anatoly A. Skvortsov[a*], Maria S. Kovyazina[a,b], Nataliya A. Varako[a,b]

[a] *Lomonosov Moscow State University, Faculty of Psychology, Moscow, Russia*

[b] *Research Center of Neurology, Moscow, Russia*

[c] *Moscow Institute of Psychoanalysis, Moscow, Russia*

*Corresponding author. E-mail: skwortsow@mail.ru

Background. Alexandria R. Luria's classic neurorehabilitation methods ("restorative learning") have now been successfully applied in clinical settings for more than seventy years. It is of interest how Luria's methods relate to contemporary strategic approaches to effective rehabilitation. One such framework is the International Classification of Functioning, Disability and Health (ICF)—a comprehensive WHO framework for measuring health and disability for diagnostic and rehabilitation purposes.

Objective. To compare Luria's procedure of restorative learning in aphasia and the ICF. Such a comparison may facilitate the use of the ICF in the work of multidisciplinary rehabilitation teams for diagnosis, planning, implementation, and evaluation of rehabilitation programs.

Design. A systematic comparison of ICF components with specific rehabilitation procedures developed by Luria aimed at speech understanding and production.

Results. Luria's speech rehabilitation methods pertain to the ICF component "Body Functions and Structures". Specific correspondences between Luria's rehabilitation procedures and ICF categories are found, especially for afferent and efferent aphasias. For the aphasias related to speech understanding (sensory and semantic aphasia), such correspondences are rare. This reflects an insufficient differentiation in the understanding of higher cognitive functions in current neurorehabilitation. Luria's concern for patients' personality and social status is also explicated.

Conclusion. Although Luria's "restorative learning" is realized within the ICF domain of "Body Functions and Structures", his approach also focuses on the rehabilitation of the personal and social status of the patient. This approach is an important condition for clinical and psychological rehabilitation in the ICF domains of "Activities" and "Participation".

Keywords:
International Classification of Functioning, Disability and Health (ICFDH), speech, aphasia, restorative learning, A.R. Luria, neuropsychology, clinical psychology, rehabilitation.

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Introduction

In recent decades, there has been rapid development of research and practical rehabilitation work regarding the fundamentals of the rehabilitation process (Wilson, Winegardner, van Heugten, & Ownsworth, 2017; Varako, Kovyazina, Zinchenko, Dobrushina, & Ivanova, 2016). At the same time, the regulatory and legal basis for rehabilitation is changing, which is reflected in the adoption of a number of international resolutions, conventions, and corresponding definitions, and also fundamentally new classifications based on the social model of health and disabilities and characterizing a person's life activity. These place a special emphasis not on the conditions of body functions, but on the abnormalities of a person's functioning.

In this vein, the World Health Organization (WHO) developed and adopted the International Classification of Functioning, Disability and Health (ICF; 2001), which is a guideline for planning and evaluation of the effectiveness of rehabilitation measures.

Meanwhile, Russia has a unique scientific school developed by L.S. Vygotsky, A.N. Leontiev, and A.R. Luria, on the basis of which a special approach emerged to the rehabilitation of affected mental functions (called restorative learning), (Luria, 1948). It seems interesting to compare the methods of restorative learning developed by Alexander R. Luria to those developed by the ICF. This comparison may facilitate communication between specialists working in various areas of science and practice. This would reflect an important principle in ICF development: the opportunity to discuss a patient's situation with all members of the rehabilitation team in a common language (the principle of neutrality) (Builova, 2013).

The ICF can be considered an important complement to the International Classification of Diseases (ICD) (International Statistical Classification of Diseases and Related Health Problems, 2016). While the latter was created as a universal means of making a medical diagnosis, the ICF is a universal tool for describing and comparing health data. Practitioners often come across the fact that the quality of life of two patients with the same diagnosis varies significantly. One person, being wheelchair-bound, loses his job, social network, and interest in life, while the second actively participates in the life of his family, leads a support group for people with disabilities, fights for their rights, etc. Such life options for people with diseases are reflected in the ICF.

The latest edition of the ICF was published in 2001. A schematic relationship of various aspects of the health and life of the individual is shown in Figure 1. A change in health conditions according to the ICF refers to a diagnosis given to the patient according to the ICD. The disease itself is also bound to affect the condition of a person's life. Characterizing the "Body Functions and Structures" component of the ICF, it is necessary to determine which structures of the patient's organism are affected and which functions (including psychological ones) of these structures have undergone a change. The description of the extent to which certain structures and functions are used by patients in real life corresponds to the "Activities" and "Participation" components of the ICF. The condition of structures and functions, as well as the extent of their use in real-life situations, are influenced by the patients' personal traits (Personal Factors) and their social and physical environments (Environmental Factors).

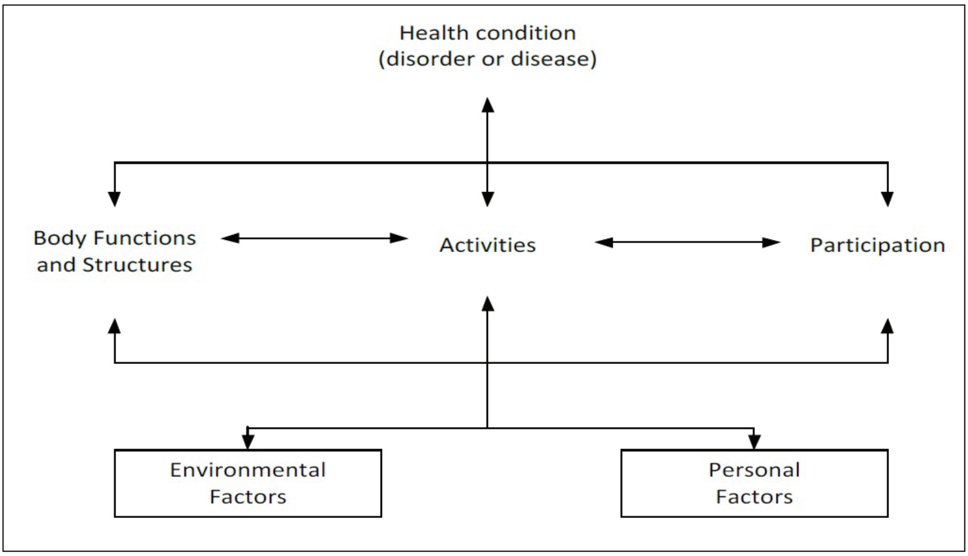

Figure 1. Interactions between the components of the ICF (International Classification of Functioning, Disability and Health, 2001).

We shall explain this scheme by using a neuropsychological example. Most experts in this field deal with patients who have suffered brain damage. Such patients may be diagnosed with "acute cerebral circulation disorder", which in the scheme described above will correspond to changes in brain function and brain structure. This diagnosis presupposes damage to various brain structures, for example, the posterior third of the superior temporal gyrus of the left hemisphere. This specification will refer to the organism structure. The primary difficulties of phonemic analysis, as well as its systemic consequences, which, as a rule, accompany damage to this structure, will characterize the functional change. Considering the "Activities/Participation" component, it is necessary to assess how much the damage to "Body Functions and Structures" influences the ability of a person to explain what he wants in a store, to maintain a dialogue with friends, to call an ambulance, etc.

This example is understood better when we consider the personal and environmental factors of the situation in which the patient lives. Personal factors may include the level of the patient's education. As a rule, the better the person is educated, the more developed is his language proficiency, which, of course, has an effect on speech processes. It can be expected that patients with higher education have a wider repertoire of speech automatisms, which to a greater extent allows them to compensate for a defect of phonemic analysis. According to Luria, patients with higher education are able to write words and whole sentences that have been reinforced by their experience "with a stroke of the pen", overcoming the phenomena of sound lability that is so characteristic of patients with sensory aphasia (Luria, 1966). In recent terminology, one could suggest that they have a higher level of available compensatory metacognitive processes (Kempler & Goral, 2008).

The physical factors important for such patients include the presence and quality of the language environment. If a person lives alone, there is no opportunity to rely on normative sound standards of words that are present in the speech of healthy people. Interpersonal relationships in which the patient is involved form the social context. It is possible that even if the language environment is physically present, the patient will not make use of it if the people providing this language environment evoke antipathy in this person. Thus, the ICF is a tool that comprehensively assesses the consequences that become especially relevant for the patient.

The most important part of the complex system of rehabilitation is psychological rehabilitation, which has several components. One particularly important area is cognitive rehabilitation. In Russia, cognitive (or neuropsychological) rehabilitation as a special area of neuropsychology involved in the rehabilitation of *higher mental functions* (HMFs), was developed by Luria. In one of his first works, *Vosstanovlenie funkcij mozga posle voennoj travmy* [Restoration of brain functions after war trauma] (Luria, 1948), the author uses the terms "long-term conscious learning", "special systematic training", "restorative learning", and "making the reorganization of defective components a matter of conscious work" (pp. 71, 74, 75). In other words, this is a set of special methods aimed at reorganizing the functional system of the mind in the process of long-term training, which initially is carried out with the maximum use of consciousness and gradually leading to the automation of these techniques. The theoretical and methodological basis of Russian neuropsychological rehabilitation is the cultural-activity paradigm of L.S. Vygotsky, A.N Leontiev, and A.R Luria.

Speech, being one of the HMFs, has its own specifics, since it organizes, connects, and reconstructs other mental functions, transferring them to the category of HMFs. Speech disorders function according to the following set of general laws: "the disintegration of higher mental functions, accompanied by pathological processes, destroys in the first place the connection between symbolic and natural processes, which start to function according to primitive laws, as more or less independent psychological structures. Thus, the collapse of higher mental functions is qualitatively opposite to the process of their formation" (Vygotsky, 1984, p. 58). Luria, describing the functional collapse caused by local damage to cortical zones, noted that they "are rarely accompanied by the complete loss of any elementary function.... Even less often they lead to a complete, irreversible disintegration of the functional system as a whole. Most often, the damage to these integrative zones leads to the disintegration of a particular functional system, which now, under pathological conditions, ceases to perform the kind of afferent synthesis that it has been performing so far" (Luria, 1948, p. 58).

Aphasia syndromes, which, first of all, bring about loss of individual speech operations, are quite illustrative. Luria suggested that, in order to compensate for the functional disintegration in aphasia, it is necessary "to organize the activity in a different way ... by incorporating it into new systemic relations in order to use residual capabilities and to compensate for this defect by taking an indirect route" (Luria, 1948, p. 61). Following Vygotsky, Luria proposes, without going beyond this partially disrupted sphere, to organize its work in a different way, incorporating it in a special form of activity related to "the history of the development of this function ... (which was subsequently automated and became known as the modus operandi of this functional system)" (p. 63). In this case, compensation is due to a conscious semantic reorganization of the functional system, which takes place as the result of prolonged special training. Luria also suggested that there is another path to reorganizing the functional system, based on the multiple (polyreceptor) composition of the afferent field of each functional system of the brain. This is the path of intersystem rearrangement. “Certain tasks can be practically solved in completely different ways; almost any disrupted component can be replaced by another, which begins to play a corresponding new role in the reintegrated system” (p. 69). This path is also rooted in historical development and in the ontogenesis of a person’s mental activity, during which the person (child) undergoes a change in operations that helps the person (child) to solve various tasks.

Such intersystem rearrangement also requires lengthy training during which the patient learns to acquire conscious control of the previously automated but now disrupted functions. After having acquired conscious control, the patient practices controlled performance of the disrupted functions until they are at least partially automated again. . “At the beginning of the training, patients become aware of their defective operations, which they have never been fully conscious of before, and start engaging new means in this process, while continuing to be aware of the techniques used. Only after quite a lengthy period (sometimes after many months) does the technique developed during training begin to become automatic, although full automation often never occurs.… Functional reorganization in these cases takes place because of the conscious mastery of new methods of activity formation”. Thus, restorative learning is not aimed at maintaining what remains intact in speech, but at the reintegration of a “psychological set of operations” of disturbed psychological processes (Luria, 1948, pp. 71–72). Today this would be phrased as using metacognitive resources for rehabilitation.

Special techniques for speech rehabilitation in patients with aphasia were studied by Luria’s colleagues and students (e.g., Ananiev & Astakhov, 1946; Bain, 1964; Bain et al., 1962; Chernova, 1958; Florenskaya, 1949; Kogan, 1962; Oppel, 1963; Tsvetkova, 1985; Zankova (Ed.), 1945). The treatment of any form of aphasia always relies on the intact speech components, which are further used to consciously compensate for the defect.

Method

The adoption of the ICF in the process of modern neuropsychological rehabilitation has made it necessary to develop special methods to evaluate the effectiveness of rehabilitation measures. New studies have increasingly attempted to correlate traditional approaches to diagnostics and rehabilitation of patients who have communication disorders, including aphasias and categories included in the ICF (Brandenburg et al., 2015; Grawburg et al., 2014; Simmons-Mackie, & Kagan, 2007; Wallace et al., 2016; Wallace, Worrall, Rose, & Le Dorze, 2017). In a survey of 24 randomized clinical trials (Xiong, Bunning, Horton, & Hartley, 2011), all the categories found corresponded to the ICF parameters. Out of 108 studies, 53% were connected to “organism functions”, 36% to “activity and participation”, and 9% to “environmental factors”. The main purpose of such comparisons is the search for the most accurate means of evaluating the effectiveness of neuropsychological rehabilitation measures. The following problem has been highlighted in the literature: Most studies of patients with communication disorders are aimed at assessing the effectiveness of applied rehabilitation measures, but they don’t take into consideration what contribution these measures make along with other factors (e.g., spontaneous function recovery).

The present article aims to analyze the process of recovering speech by reorganizing its functional system, as described by Luria in his early works (Luria, 1947, 1948), in the context of the ICF.

Results

Luria focuses on two aspects of speech: speech production and speech understanding. The basis of the separation of different forms of aphasia for Luria was analysis of local brain lesions and the description of neuropsychological factors that underlie the entire complex of disorders arising from localization of the lesion. Luria studied and described seven forms of aphasia: efferent motor, afferent motor, dynamic, sensory, acoustic-mnestic, semantic, and amnesic (Luria, 1947, 1948).

Recovery of speech production with traumatic aphasia

With *afferent motor aphasia*, the task of rehabilitation is a radical reorganization of the functional system of verbal praxis, the replacement of disintegrated kinesthetic schemes by motor schemes not based on kinesthetic afference. According to the ICF, this will fall into the category "Articulation functions. Functions of the production of speech sounds", coded as *b 320*. The therapy will include the use of less damaged elementary, involuntary, or transitive movements with the tongue or lips (spitting out tasteless food, blowing out candles, etc.). For example, to get the sound "P", the patient is given a burning match to blow out so that he focuses on the constituent components of this movement. Further, to consolidate the result obtained, the patient is offered reinforcement using unimpaired analyzer systems: showing the position of the lips to the patient during pronunciation of the sound; squeezing and releasing the patient's lips; pressing the chest; observing the proposed auxiliary schemes and images in order to understand the formation of the corresponding sounds; reliance on unimpaired writing abilities. Then, through the differentiation of the labial P sound, the labial sounds B and M are trained. After that, the letter is involved in the rehabilitation work, which makes it possible to generalize different variants of its sound and to differentiate sounds whose articulatory structure is similar but which still belongs to other phonemic categories. These rehabilitation procedures will make it possible to proceed to the articulation of simple words. This more advanced stage of speech production in Luria's rehabilitation method corresponds to the ICF category *b 3308* (Fluency and rhythm of speech functions, other specified).

With *efferent motor aphasia*, the main goal of Luria's restorative learning is recovery of sound combinations and sequences of sounds in a word, as well as the recovery of the motor schemes of intact comprehensive speech. Given its complexity, it is unsurprising that this goal corresponds to several ICF categories: *b 3300* "Functions of the production of smooth, uninterrupted flow of speech"; *b 3301* "Functions of the modulated, tempo and stress patterns in speech"; *b 3308* "Fluency and rhythm of speech functions, other specified"; *b 176* "Specific mental functions of sequencing and coordinating complex, purposeful movements"; *b 1672* "Mental functions that organize semantic and symbolic meaning, grammatical structure and ideas for the production of messages in spoken, written or other forms of language".

Luria differentiated three stages of the rehabilitation work in efferent motor aphasia. In the first of them, "sound training" occurs, the goal of which is not to master typical articulation, but to transform the articulation of the "pure phoneme" into the articulation of its "positional variants", i.e., nuances that every sound of speech acquires when included in a syllable or a word (codes *b 3300, 3301, 3308*). Among the basic methods of restorative learning at the first stage is training on the internal scheme of a syllable or word, training on a number of simple sound combinations (for example, PA-AP, MA-AM), relying on auxiliary graphic schemes, tracking the sequence of sounds in similar words (for example, TAKE and KATE), putting together syllables and words out of separate letters, reliance on writing and reading, etc.

At the second stage of the restorative learning, rehabilitation procedures are aimed at the analysis of morphological and semantic aspects of a word (*b 1672*). This is important, as the unity of sound and meaning in the acute period of brain damage is disrupted and sound combinations lose their meaning. Acquiring the skill of word root isolation and the formation of a word family from this root makes it possible to expand the diapason of speech production used by the patient.

At the third stage of rehabilitation in efferent motor aphasia, the goal is recovery of the grammatical aspects of an utterance (*b 1672*). This stage is necessary because while the nominative function of a word may be preserved, its predicative aspect might be lost in efferent motor aphasia. During this rehabilitation stage, the patient is given tasks containing two-word utterances. To realize that the utterance should always have a predicate, the patient is asked to view pictures and describe the actions depicted in them, to fill in omissions in the text with the appropriate predicates, and to work on the grammatical change of the word in the utterance.

Recovery of speech understanding with traumatic aphasia

The rehabilitation of a patient with *sensory aphasia* starts with restoring the correct sound analysis of the word and obtaining stable and generalized sound (phonemic) groups. This corresponds to the ICF code *b 16700* (Mental functions of decoding spoken messages to obtain their meaning). To this end, the patient is advised to rely on the meaning of the word. For example, a patient analyzes a series of words that sound similar (for example, GAME and CAME). Writing helps, too, since working on letters ("graphemes") allows the patient to understand the generalized symbols of the sounds, to isolate individual sounds in the complex composition of the sounds of a word, to become aware of the presence of vowels, and to decompose the complex sets of consonants. Kinesthetic and optical support are provided by palpation of the larynx, observation of differences in the exhaled air, use of object images with descriptions, etc.

At the next stage, Luria suggested restoring the semantic aspect of speech. These rehabilitation procedures are based on methods that help to establish the constant meaning of the stem of a word. This task is realized with the help of exercises aimed at giving semantic consistency to words that have changing forms. Tasks offered to patients are associated with inclusion of words in fixed phrase constructions with a constant meaning, for clarifying the semantic aspects of the word. Afterwards, the meanings of the same word are mastered in several semantic contexts with different phraseological contexts. Special attention is given to the suffixes and inflexions of the word.

Overcoming *semantic aphasia* involves the recovery of understanding of grammatical relationships within spoken utterances. Although this is certainly a complex set of cognitive abilities, the only ICF code that seems to correspond to it is still *b 16700* (Mental functions of decoding spoken messages to obtain their meaning). The general approach of restorative learning for semantic aphasia consists of replacing the immediate "observation of relations" by the patient, using surface features like word proximity within an utterance, with consistent reasoning based on a number of external auxiliary aids. Among the techniques developed by Luria, the most important is mastery of grammatical constructions that express semantic relations between entities. This can be demonstrated by a classic example of patients learning to differentiate the meanings of the utterances "The sun is eclipsed by the moon" *vs.* "The moon is eclipsed by the sun". Other techniques include reliance on inflections and awareness of the form of the main word and the addition of a demonstrative pronoun serving as an external orienting sign and playing the role of an indicating gesture, deixis ("The brother of this father"). At the final stage of Luria's restorative learning of patients with semantic aphasia, the patient gets a grasp of the semantics of prepositional constructions based on pictorial schemes (under / below, over / above, etc.).

On a general note, there is a striking difference in the correspondence between speech functions targeted by Luria's rehabilitation methods and the ICF categories. For speech production aphasias, there is an abundance of correspondence. This may reflect the obvious fact that dysfunctions in motor and sensory areas are very well described by contemporary neuroscience and medicine, so that detailed links between Luria's rehabilitation procedures and the ICF codes can be established. This close correspondence allows one to see, for example, that Luria's rehabilitation methods developed in the 1940s reflect the idea, now widely accepted, of a vertical organization of cognition (Challis & Velichkovsky, 1999). Luria's rehabilitation methods for efferent motor aphasia, for example, gradually progress through mastering the most basic (data-driven, bottom-up) aspects of sound production, to mastering much more abstract (conceptually driven, top-down) speech production rules. However, for aphasias related to speech understanding, only one correspondence with the ICF categories could be found. This is despite the fact that Luria's rehabilitation methods are very well developed also in this respect. The lack of differentiation of functions related to speech understanding in the ICF surely reflects a lack of full understanding in contemporary neuroscience and medicine of higher order cognitive functions related to conceptual/semantic processing. In this respect, Luria's system of rehabilitation procedures may serve as a conceptual and empirical basis for future research in this area.

Luria's aphasia rehabilitation and other ICF components

Comparison of the process of Luria's speech rehabilitation procedures in different forms of aphasia with the components of the ICF showed that the main work carried out by a neuropsychologist in Russia is carried out within the domain of the ICF "Body Functions and Structures". Even within this domain, Luria advanced the use of the holistic syndrome approach in the rehabilitation of patients with local brain lesions. These rehabilitation methods are focused on the patient's specific mental processes, many of them of a metacognitive nature. Within this syndrome approach, rehabilitation exploits syndrome-forming mechanisms. While Luria's rehabilitation procedures seem to set aside the properties and structure of the personality (Luria, 1966), Luria's rehabilitation methods are always applied in the context of patients' activities, spontaneous behaviors, and social relations. For instance, special attention is given in Russian neuropsychology to patients with an objectively high recovery potential, who, however, lack the motivation to work with a neuropsychologist, or to patients who are fundamentally unable to restore impaired functions at the level of restructuring the brain's functional systems, due to depression and impaired consciousness. Luria understood these limitations very well and stated them explicitly: "This possibility is due to the fact that the functional systems of the brain are based on the interaction of many areas. In cases where the brain injury leaves unaffected the apparatuses directly connected with the retention of stable motives and does not lead to an anatomical inability to create new functional relations between individual regions of the brain, the patient will always have a way to compensate for the defect by adjustment of functional systems " (Luria, 1948, p. 774). Thus, Luria never forgot about the patients' functioning, their activities, and always showed an interest in specific individual behavior. This is shown in his famous case studies illustrating the ideas of "romantic medicine", such as *The Mind of a Mnemonist* (Luria, 1968) and *The Man with a Shattered World* (Luria, 1972). Such an approach corresponds very well with the introduction of the Activities/Participation components into the ICF.

Conclusion

In the modern approach to the rehabilitation of patients with aphasia, the ICF makes it possible to design and evaluate the process of cognitive rehabilitation at psychologically different levels: from the physiological support of cognitive processes, to the level of individual social relations. We have explicated how elements of the classic approach to the neurorehabilitation of aphasias developed by A.R. Luria in the 1940s are related to the ICF categories. We have shown that Luria's methods of rehabilitation of speech production fit well with the ICF categories, and that Luria's methods of rehabilitation of speech understanding still seem to be much more differentiated than the classifications proposed by the ICF. We have also tried to show that while Luria's rehabilitation procedures are more within the ICF "Body Functions and Structures" domain, in Luria's neuropsychology there was always a special consideration of patients' activities, personalities, and environments. This is in close correspondence with the contemporary philosophy behind the ICF. Thus, restorative learning based on Luria's theory of systemic-dynamic localization of higher mental functions takes its rightful place in rehabilitation of patients with brain lesions and in the complex interrelated structure of ICF domains.

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Eye Movements and Word Recognition during Visual Semantic Search: Differences between Expert and Novice Language Learners

Irina V. Blinnikova[a*], Maria D. Rabeson[a], Anna I. Izmalkova[a]

[a] *Lomonosov Moscow State University, Moscow, Russia*

[*] Corresponding author. E-mail: blinnikovamslu@hotmail.com

Background. The empirical studies in visual word recognition done over the past years have been focused on the influence of contextual, lexical, and semantic properties. Researchers also have taken into consideration the role of individual differences in the word recognition process, e.g., vocabulary knowledge.

Objective. This study focuses on the cognitive strategies used by expert and novice language learners in a visual semantic search task. Our hypothesis is that the level of ESL (English as a Second Language) mastery would influence the word recognition and oculomotor patterns applied by the participants.

Design. The participants–native Russian speakers–were divided into three groups according to their level of English language mastery. The experimental task involved a search for horizontally- or vertically-oriented English words in letter matrices (15*15); the frequency and length of the words varied. Performance measures (number and orientation of the found words) were registered, along with the participants' eye movements.

Results. Word search efficiency depended on the frequency, length, and orientation of the words and the participant's language mastery; however, these factors did not interact. The data show that oculomotor events are denser in experts' results. Learners with different levels of language mastery use different information-processing patterns, which are reflected in the proportions of fixation and saccade durations. Two complementary trends were found: word search efficiency is effected, first, by a longer gaze scan path, and second, by the focal mode of visual information-processing, manifested in a combination of longer fixations and shorter saccades.

Conclusion. The registration of eye-movement patterns in visual semantic search tasks reveals the characteristics of effective and non-effective cognitive strategies used by ESL students at different levels of language competence.

Keywords:
visual semantic search, word recognition, expert and novice language learners, SL competence, eye-movement, cognitive strategies, visual information processing.

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Introduction

Visual word recognition is a dynamic field in which there have been a lot of broad theoretical developments and rich empirical literature (Yap & Balota, 2015). The empirical research in visual word recognition has focused on the influence of contextual, lexical, and semantic properties (Brysbaert & New, 2009; Pexman, 2012). A more recent approach takes into consideration the role of individual differences in the word recognition process, e.g. vocabulary knowledge (Yap, Tse, & Balota, 2009) and reading disabilities (David & Metsala, 2015). However, the cognitive microstructure for word recognition in skilled and novice language learners has not yet been subjected to empirical study, as it has been for reading tasks, although numerous attempts have been made to reveal the nature of the cognitive processes used in reading through the analysis of eye movements (Dare & Shillcock, 2013; Rayner, 2009).

The transformation in information processing that occurs while learning, has attracted the attention of researchers since the beginning of the 20th century (Haider & Frensch, 1999). The issue is often investigated through comparing the performance of experts and novices in cognitive tasks (Chase & Simon, 1973; Reingold & Sheridan, 2011). Experts have extensive and deep knowledge, as well as resources for effective problem-solving in their professional areas. They contrast with people who are beginning to master the area of knowledge or skill, or those who have not achieved high levels of mastery (Feldon, 2007). K.A. Ericsson emphasized that "one of the most exciting challenges in cognitive science is to understand the mechanisms mediating the superior performance of experts in various domains, such as chess, physics, medicine, sport, dance, and music" (Ericsson, 1991: vii). Indeed, this understanding opens up new opportunities not only for the modeling of cognitive processes, but also for developing new systems of assessment and training for professionals.

Eye-tracking methodology[1] has provided significant insight into the perceptual mechanisms underlying the difference in performance between experts and novices. There is a lot of evidence identifying the specific perceptual patterns used by experts as they solve visual tasks in their fields. The level of expertise in visual tasks has been investigated in eye-movement studies of chess players (Grigorovich & Zyzlova, 2016; Reingold & Sheridan, 2011); medical staff (Wood, Batt, Appelboam, Harris, & Wilson, 2014); teachers (Asaba, 2018; Wolff, Bogert, Jarodzka, & Boshuizen, 2014); chemists (Blinnikova & Ishmuratova, 2017) and others. All the above-mentioned studies showed significant distinctions between the eye movement patterns of experts and novices in their fields.

The main characteristic of experts' eye movements in visual tasks is greater "fluency" of viewing and attention to informative details, which is probably due to their deeper knowledge of the subject (Gegenfurtner, Lehtinen, & Säljö, 2011). For instance, it took only one fixation for grandmasters to find the position of a given

1 Eye-movement measures such as fixation duration, fixation count, AOI first hit and dwell times, saccadic amplitude, and regression count are most often taken into account (see Holmqvist et al., 2011). Attempts have been made to elaborate integrative oculomotor indicators: the saccade-fixation ratio (Kotval & Goldberg, 1998), focal and ambient modes of exploration (Velichkovsky, Joos, Helmert, & Pannasch, 2005), and change in the saccadic angles (Blinnikova & Izmalkova, 2017).

piece on the chess board (Chase & Simon, 1973; Reingold & Sheridan, 2011). In the task of proof validation, skilled mathematicians tended to shift their attention between consecutive lines of purported proofs and distribute their attention in favor of implicit warrants, whereas undergraduate students spent more time focusing on the algebraic computation ("surface features" of the arguments) (Inglis & Alcock, 2012). Moreover, experts tended to find "shortcuts" to relevant information in complex visual stimuli (Jarodzka, Scheiter, Gerjets, & Van Gog, 2010). This idea is called the information-reduction hypothesis, which postulates that "with practice, people learn to distinguish task-relevant from task-redundant information and to ignore task-irrelevant information" (Haider & Frensch, 1999: 129). Similar changes can take place with the increase in language proficiency.

The fields of language acquisition and linguistic competence necessary to provide verbal information processing stand somewhat apart. When N. Chomsky (1965) introduced the concept of linguistic competence, he implied competence in one's native language. It is acquired early in childhood, which means that many of the fundamental cognitive attributes that ensure a high level of performance in verbal tasks remain hidden, despite attempts to reveal them (Carlson, Seipel, & McMaster, 2014). When analyzing language development in childhood, it is difficult to distinguish between the linguistic system proper and the systems of perception, memory, and thinking (Verhoeven & Leeuwe, 2009). Some significant characteristics of linguistic competence can be revealed in the process of mastering a foreign language (Blinnikova & Izmalkova, 2016; Mishra, Singh, Pandey, & Huettig, 2012). But this approach gives rise to several difficulties, the main one being the interaction between the developing systems of a second language (SL), and the already existing systems of the native language. However, a careful analysis of the change in verbal information-processing as the SL is being mastered, makes it possible to identify the main trends in the development of linguistic competence.

In the research on foreign language learning, the most frequent index for SL experience is language proficiency. One of the necessary skills formed during language learning is the ability to recognize lexical units, which involves matching a perceived stimulus to the representation in a person's mental lexicon[1]. The ways a mental lexicon is addressed have been broadly discussed recently (Libben & Titone, 2009). Attempts were made to establish whether this process relies on literal analysis, or rather that the words are perceived as holistic patterns (Grainger & Dufau, 2012). The existing models (Yap & Balota, 2015) suggest that there are at least two levels of analysis that determine the depth of information processing: incoming information processing (sub-lexical) and semantic analysis (lexical). Some researchers identify different strategies of information processing in the process of word recognition[2]. For example, D.A. Balota and D.H. Spieler (1999) describe two main strategies: a fast-acting familiarity-based process and a slower more attention-demanding process. The research into visual recognition of words often in-

1 The mental lexicon is known as a mental dictionary which contains information about a word's pronunciation, meaning, syntactic attributes, and so on, (Jackendoff, 2002). In linguistics and psycholinguistics Mental Lexicon is used to refer to individual speaker's lexical, or word, representations.

2 According to Wolf and Katzi-Cohen (2001), word recognition is a summation of accuracy and speed of meaning access through decoding of printed words.

volves the following tasks: reading, naming, categorizing, perceptual identification, lexical decision task, etc. (Yap & Balota, 2015). To gain a better understanding of the processes behind word recognition, researchers try to figure out how different characteristics (such as word frequency, length, familiarity, etc.) affect performance on the recognition task (New, Ferrand, Pallier, & Brysbaert, 2006; Norvig, 2013).

Eye-movement indicators have been used to identify the cognitive architecture of information processing and word recognition while reading, in people with different linguistic competence (Kunze, Yoshimura, Kawaichi, & Kise, 2013; Leinenger & Rayner, 2017). In K. Rayner's classic work on eye movements in reading and information processing, significant distinctions were found in the eye movements of individuals with different reading expertise: more experienced readers demonstrated longer saccadic amplitude, shorter fixations, and fewer regressions, while less skilled readers exhibited shorter saccades, longer fixations, and more regressions (Ashby, Rayner & Clifton, 2005; Rayner, 1998;). These data indicate that the development of reading skills leads to faster eye movements and faster information processing. As skills and word familiarity increase, more rapid linguistic analysis strategies are used (Clifton et al., 2016; Schotter & Rayner, 2015). Also, people learn to better organize their oculomotor activity, which helps them get more information within shorter intervals (Kunze et al., 2013). With an increased proficiency level, the duration of eye fixation in recognizing words is significantly reduced, although the number of eye fixations of low-proficiency SL readers is the same as those of high-proficiency SL readers (Bernhardt, 1984; Dare & Shillcock, 2013).

Since SL reading and word recognition form a task of a higher complexity than in one's own language, fixations get longer, saccades get shorter, and more regressions occur while performing (Rayner, 1998). Research in SL reading considers a number of additional aspects, including elements such as orthographic background, print input properties, SL experience, reading skill (Rayner, 2009), and an interplay of these elements (Koda, 2007). These factors have also been considered in SL word recognition research aimed at investigating the relationship between word recognition and reading outcomes (Han, 2015; Koda, 2007; Yamashita, 2013).

In our opinion, the task of reading, especially native language reading, creates special conditions which imply that the subjects recognize words placed in a semantic context rather than individual words. This allows the readers to refer only to a limited part of his/her mental lexicon and naturally facilitates the task of recognition, sometimes to the extent that all operations become implicit. Therefore, we were interested in identifying a more difficult task that would reveal the cognitive processing through eye-movement analysis of word recognition strategies in people at varying levels of linguistic competence. We assumed that visual semantic search tasks, which involve detecting a target object on a screen filled with distractors, could be used in the research.

One of the instruments for investigating semantic search is to use a stimulus matrix that consists of random letters. Participants start the search, unaware of which word to look for, and with the goal of finding any correct word. This task combines reading and lexical decision tasks. Just as in reading, the subject has to scan the space filled with letters. However, unlike in reading, eye movements are unguided and less organized. Just as in a lexical decision task, the subject must constantly analyze whether the letter string is a word, but, in contrast to the lexical decision task, it is the subject who highlights which chain of letters to consider. We believe this task will allow us to reveal the complex processes lying behind word search and recognition, and to identify the mechanisms which differentiate people at various levels of competence.

Method

Goal

Our study focuses on the eye-movement patterns of ESL learners at different levels of mastery. As previous studies of oculomotor activity patterns in the context of cognitive strategies in various tasks (Blinnikova & Izmalkova, 2016; Blinnikova, Izmalkova, & Semenova, 2016) have shown, oculomotor correlates can indicate the characteristics of information processing (Rayner, 2009). Thus, the registration of participants' eye-movement patterns while they are performing semantic search and word recognition tasks is expected to reveal the features of the cognitive strategies used by ESL students at different levels of linguistic competence. The core goal of the research is to highlight the specific oculomotor activity patterns which can be associated with an increase in linguistic competence and, therefore, can reveal the development of cognitive processing strategies leading to higher levels of semantic search performance.

Sample

The sample included 32 undergraduate students aged 18-22, and 15 postgraduates aged 23-33. The participants were selected to form three homogeneous groups based on the parameter of English language mastery tested with the Word Associates Test (Read, 2013). In group one, the average language competence of the students corresponded to A2 (elementary-novices); in group two, it was B1-B2 (intermediate/vantage-users); and in group three, it was C1 (proficiency-experts), with A2, B1-B2, and C1 being levels set by CEFR (The Common European Framework of Reference for Languages). All the participants gave their written informed consent prior to the experimental procedure.

Stimuli

A Word Search task assumes that the person tries to find meaningful lexical units in a random set of letters. The subject consistently analyzes a string of letters, which he/she checks for lexical relevance. The solution has a complex cognitive architecture, including word recognition and a set of lexical decisions. For stimulus material, we generated letter matrices from randomized letters selected in accordance with the frequency of their appearance in English language. To do so, we created a randomizing procedure which used English letter frequency data (Norvig, 2013). This procedure was carried out to form letter matrices (15 by 15 letters each).

Then, the sets of target words were placed in the matrices (see *Figure 1*). The target words were separated by at least one row of letters and never crossed each other. Each matrix contained 10 English words, horizontally and vertically oriented. Thus, the parameter of spatial orientation of the target word was controlled in every trial.

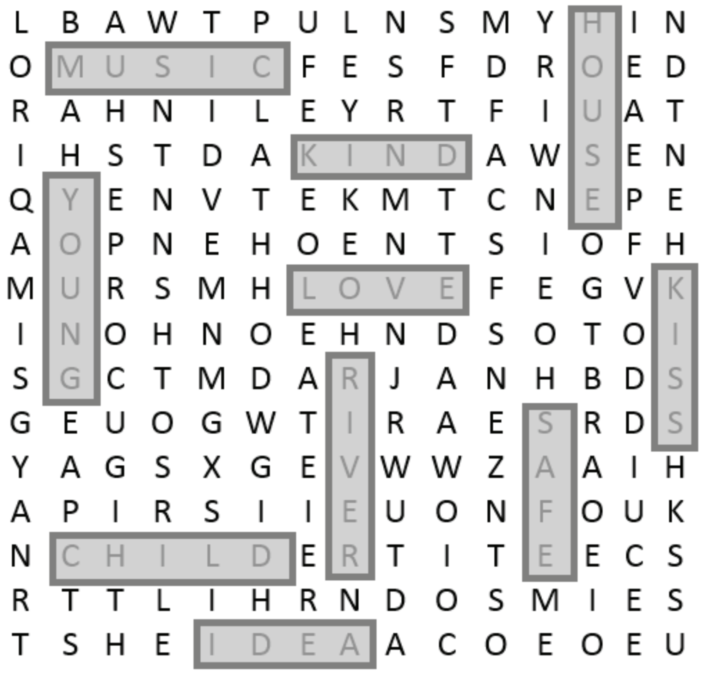

Figure 1. Sample stimulus matrix with marked target words

Two series of the experimental procedure tested the factor of word length. The first series included words of four, five, and six letters. In the second series the length of the target words exceeded six letters. The ANEW scale (Bradley & Lang, 1999) was used to perform the target word selection according to word frequency data. The three groups were labeled as frequent, average, and rare words. Thus, the stimulus material consisted of 18 letter matrices, varying in the target word length and frequency. The incidence of distractors was under control. Three experts checked and proofread the matrices prior to the experimental procedure.

Procedure

Our experimental design included two consecutive series of stimuli exposure for each participant. The experiment was conducted individually. First, a subject filled in a questionnaire on his/her biographical and educational background, language mastery, and current physical condition. Then the subjects were tested for English language verbal competence. A printed version of Word Associates Test (WAT) (Read, 2013) was used to evaluate it. Later, the WAT results were used to group the participants according to their verbal competence.

The experimental procedure called for all the participants to be provided with printed instructions, and they had time to prepare for the experimental session. They were instructed to look for meaningful English words, vertically or horizontally oriented, in the matrices they would see on the screen. The words ought to have a minimum of four letters. The identified word was to be marked by mouse clicks of the first and the final letter. This method was meant to decrease the number of incidental strikes on the target words, as can happen in the case of fixations on Areas of Interest (AOI[1]). Each subject took part in two consecutive experimental series, divided by a short break for releasing the muscle tension which accumulated during holding the body in a fixed position during the experiment. Each series included nine matrices presented on a screen for 40 seconds, with a calibration fixation screen between them. The apparatus was calibrated in the beginning and after the first five matrices of each series.

Registered parameters

The number and spatial orientation of the found words were registered. We also registered the following oculomotor activity parameters: fixation count and duration; saccadic count, duration, amplitude, and velocity; and scan path length. Moreover, the target words were marked as Areas of Interest on stimuli matrices, which allowed us to register the eye-movement parameters within the target areas. These included AOI dwell time, fixation time and average duration, first fixation duration, glance duration, revisits, entry time, and the first click time.

Technical equipment and software

We used the following technical equipment: “SMI Gaze & Eye-tracking System” hardware and software; “Experiment Centre” software in experimental design; and the SMI RED 250 Hz eye-tracker. The distance between the monitor and eye was set at 0.6-0.8 m; precision at 0.4°; spatial resolution (RMS) at 0.03°; maximum delay at 6 ms; automatic calibration at <10 sec. The mouse clicks were registered. IBM SPSS Statistics 19 was used for data analysis.

Results and Discussion

For each subject 18 trials were registered. In the processing of samples, we treated each record as a separate case. We considered this possible because from the beginning we aimed at identifying the strategies leading to success that could vary from trial to trial.

The influence of the main and additional factors on the word search performance

The experimental task proved to be quite difficult for the subjects. In each individual trial, the participants found from zero to six words. However, the task was quite sensitive to the level of foreign language mastery. The means comparison indicates that task performance efficiency increased through all three groups of participants (see *Table 1*), with the novices having the lowest scores, and the experts showing the highest result. The differences proved significant. The same trend was observed throughout the results for horizontally- and vertically-oriented words (see *Table 1*).

[1] “AOIs define regions in the stimulus that the researcher is interested in gathering data about” (Holmqvist et al., 2011: 187).

Table 1
Word search efficiency

	Recognized Words Count		
	General Efficiency	**Horizontal Orientation**	**Vertical Orientation**
Novices	0.99	0.83	0.15
Users	1.69	1.52	0.16
Experts	2.22	1.91	0.31
F(2;796)	71.31	63.65	8.27
Significance	p<0.001	p<0.001	p<0.001

Differences depending on spatial orientation, word frequency, and length effects were detected. It was much easier for all the participants to find the words that were horizontally positioned. On average, the subjects found 1.39 horizontally located words per matrix, vertically located words were found about seven times less often (0.20 — the differences are highly significant). This result may indicate that the subjects used strategies similar to those they use when reading. Identifying the characteristic scanning patterns is a task for further analysis.

The data also indicate that it was much easier for subjects to find long words rather than short ones (see *Figure 2*). With short and long words presented in different series, participants found an average of 1.83 long words and 1.34 short words per matrix. The differences are significant ($F(1;797)=30.24$; $p<0.001$). These results were unexpected since in most word recognition tasks (such as reading, pronouncing out loud, perceptual identification, lexical decision, etc.), the difficulty of the task increases with the increase in word length — i.e. latent reaction time grows (Yap & Balota, 2015). The words containing more letters require longer latent subprocessing time (Oganian et al., 2015). In our case it turned out that longer words appeared more “noticeable” for the participants. Apparently, the search for short

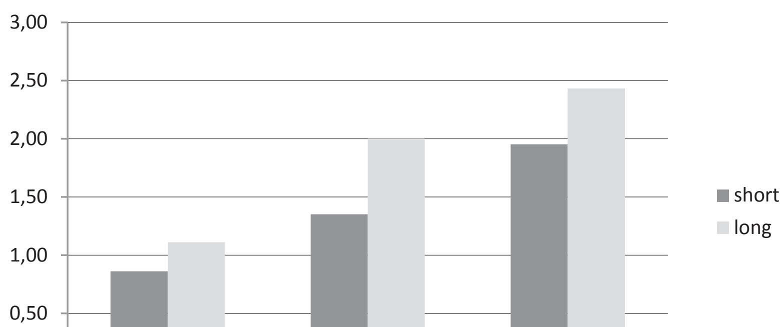

Figure 2. The number of found words depending on their length in groups of different language competence

words is under greater influence of distractors, when subjects have to process a lot of related information. The longer words set-up allows the reader to avoid a large number of deceptive lexical units.

The effect of frequency is shown in *Figure 3*. The words of higher frequency were more likely to be detected in the current study. On average the subjects found 1.97 high-frequency words, 1.66 midrange words, and 1.23 low-frequency words per matrix. The differences calculated for all the trials are highly significant $F(2;796)=27.50$; $p<0.001$). The fact that high-frequency words are easier to recognize, which is expressed in higher reaction speed and recognition rating, has been repeatedly confirmed. Nevertheless, the mechanisms explaining the effects of frequency are not completely clear (Kinoshita, 2015). In our case, the simplest explanation is that low-frequency words are more difficult to distinguish from non-words, and this makes it difficult to identify them (Yap & Balota, 2015).

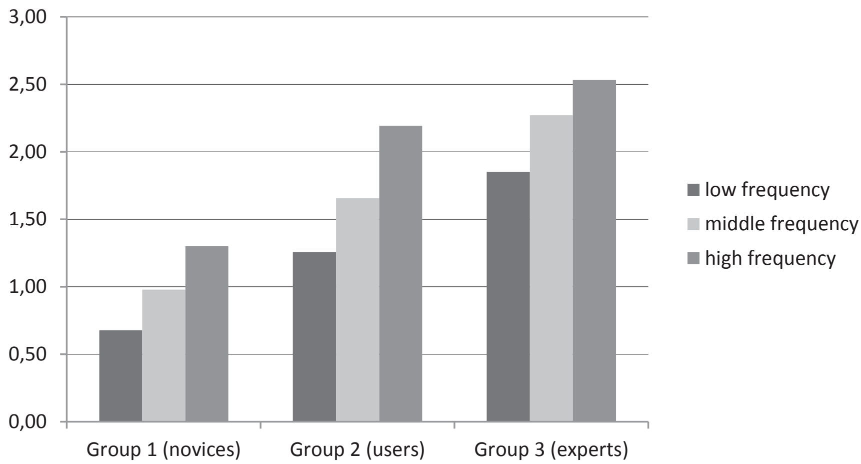

Figure 3. The number of found words depending on their frequency in groups with different language competence

No interactions were found between the factors of spatial orientation, length, and frequency of words, and the factor of foreign language competence. In the groups of participants at different levels of language mastery, the influence of those three additional factors was unidirectional.

Oculomotor activity patterns in participants with different levels of linguistic competence

When analyzing oculomotor activity in the participants, we found that the development of language mastery is associated with higher gaze coverage of the matrix areas. Thus, oculomotor events occur much more frequently in the experts' results than in the novices' results (see *Table 2*). Experts show shorter fixation durations and longer saccade durations as compared to users and novices. The same trend is reflected in saccade velocity and scan path length increase. For instance, the mean scan path length rises from 16821.07 pixels for novices, through 18165.47 pixels for users, to 20776.40 pixels for experts; that result is significant at $F(2;796)=46.82$; $p<0.001$.

Table 2

Stimulus matrix coverage by eye-movements: Intergroup comparison

	Oculomotor Events count (Fixations/ Saccades)	Fixation Duration Total(ms)	Saccade Duration Total(ms)	Saccade Velocity Average (Bdeg per s)	Scan path Length(px)
Novices	135.31/137.38	34552.54	3460.76	91.75	16821.07
Users	144.22/146.55	31715.48	6167.42	94.43	18165.47
Experts	146.37/149.23	29977.12	6410.42	109.14	20776.40
F(2;796)	17.84/19.03	35.62	40.77	19.72	46.82
Significance	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

Data analysis also shows that learners with different levels of language mastery use different types of information processing, which are reflected in the proportions of their fixation and saccade durations (see Table 3). The word search and recognition process is characterized by longer fixations and shorter saccades in the group of novices in the English language. The group of experts, on the other hand, demonstrates shorter fixations and longer saccades. The same pattern persists in average saccade amplitudes with the group of experts having twice as high values as the group of novices.

Table 3

Information processing measures: Intergroup comparison

	Oculomotor Events Frequency (Fixations/ Saccades) (count/s)	Fixation Duration Average (ms)	Saccade Duration Average (ms)	Saccade Amplitude Average (Bdeg)
Novices	3.42/3.45	259.65	24.74	3.19
Users	3.62/3.69	221.22	43.69	5.63
Experts	3.65/3.72	203.90	47.68	6.92
F(2;796)	11.52/15.58	105.98	30.70	32.42
Significance	p<0.001	p<0.001	p<0.001	p<0.001

In general, these data confirm the general trend established in the previous analyses of eye movements while reading. K. Rayner and his colleagues have shown that the increased competence in reading, and/or reduced complexity of the text, lead to an increase in reading speed and saccadic amplitudes, and a decrease in average fixation durations (Rayner, 2009; Schotter & Rayner, 2015). Similar trends are also observed in chess playing, visual medical information analyzing, etc. These changes reflect skill development in a particular area of expertise (Feldon, 2007). Information processing and access to mental lexicons are becoming more and more automated as the information-reduction mechanisms start to operate (Haider & Frensch, 1999).

Areas of Interest analysis shows that there are significant differences in oculomotor activity patterns in the region of successfully identified words, compared to the AOIs with words which were not found by the respondent (see *Table 4*). For instance, the AOI dwell time associated with correct target word identification exceeds by almost three times the same parameter for the unidentified words. Another factor contributing to the successful search, is the number of AOI revisits which are higher for the found words. Additional analysis is required to identify the cognitive architecture of this process.

Table 4

Oculomotor events in the Areas of Interest (AOI) for the found and not-found words

	AOI Dwell Time (ms)	**Average Fixation Duration in AOI (ms)**	**First Fixation Duration in AOI (ms)**	**Revisits count (number)**
Not found word	852.21	160.90	158.86	2.31
Found word	2436.64	226.07	198.11	3.41
F(2;7987)	159.,72	283.16	77.86	177.43
Significance	p<0.001	p<0.001	p<0.001	p<0.001
Significance	p<0.001	p<0.001	p<0.001	p<0.001

The duration of the first fixation, as well as the duration of the average fixation in the AOI, is higher for the found words, which can indicate that correct lexical decisions are taken only in case of deeper semantic processing, associated in its turn with longer timespans. It is significant that both indicators are not too high as compared to the average in the case of the found words; rather, on the contrary, the fixations in the areas of the missed words are too short. These data require further analysis. Most likely, we are faced with the phenomenon of word skipping. K. Rayner assumes that approximately one third of words are skipped when reading (Rayner, 2009; Schotter, Rayner, 2015). It is noted that these words are either too short, or highly predictable and out of context. This habit of skipping words seemed to mislead the participants in our experiment. They relied on their reading skills in a task that required other strategies of verbal material processing.

Analyzing the intergroup differences in eye-movements during successful target word recognition (see *Table 5*), we find that, along with the gradual decrease in AOI dwell time from novices (3089.83ms), through users (2317.29 ms), to experts (2161.19 ms) ($F(2;1166)=22.95$; $p<0,001$), the duration of the first and the average fixation breaks the trend. This finding can indicate some qualitative change in semantic processing with the growth of language mastery, whereas the unsuccessful AOI hits only reflect the general trend toward shorter fixations with the increase in linguistic competence.

Table 5

Intergroup comparison of the oculomotor events in AOIs (found and not-found words)

	AOI Dwell Time (ms)		**Average Fixation Duration in AOI (ms)**		**First Fixation Duration in AOI (ms)**	
	Found	**Not found**	**Found**	**Not found**	**Found**	**Not found**
Novices	3089.83	963.62	265.10	175.42	233.87	174.35
Users	2317.29	818.54	209.56	157.60	180.81	154.93
Experts	2161.19	742.89	217.37	145.36	191.94	142.79
	F(2;1166)= 22.95	F(2;6817)= 24.06	F(2;1166)= 21.27	F(2;6817)= 34.56	F(2;1166)= 15.20	F(2;6817)= 28.74
Significance	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

The time between the first AOI hit and the first mouse click in the same area reflects the normal trend for shorter reaction times in experts. Novices tend to spend more time for their lexical decision (see *Figure 4*). Differences are significant at F(2;1166)=5.82; p=<0.003.

Trials with high and low success levels

The eye-movement patterns we observed are associated with an increase in language competence and indicate the development of a more automated processing of verbal information. However, it remains unclear which scanning strategies and information extraction types provide a more efficient recognition of words in a noisy context. In searching for a reliable answer, we attempted to compare eye movements in more and less successful trials.

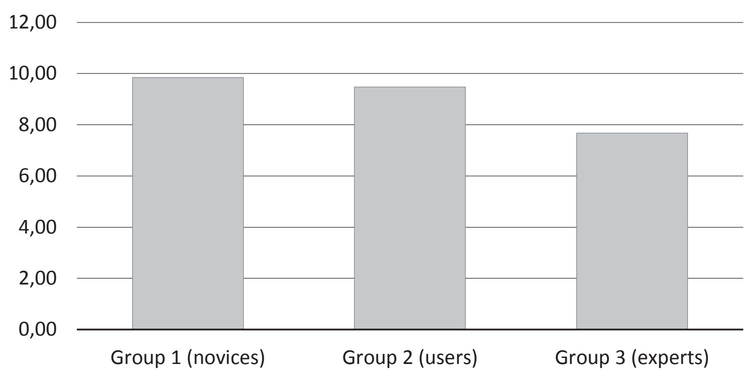

Figure 4. Average decision time–the time from the first entry into the AOI in the letter matrix to the click on the computer mouse highlighting a recognized word –in groups with different foreign language competence

We divided each of the three groups of subjects into two subgroups, successful and unsuccessful trials, with the following results:

- In the group of novices, unsuccessful trials (n=131) amounted to 45.5%; they didn't find a single word. All other trials (n=157) were classified as successful (54.5%).
- In the group of users, unsuccessful trials were the ones in which 0 or 1 word was found (n=124), which amounted to 46.1%. Trials in which the subjects found from 2 to 6 words (n=157) were classified as successful (53.9%).
- In the group with good knowledge of English, not only the trials in which the subjects found no words (they were only 18, or 7.4%), but also those in which only one or two words were found, were classified as unsuccessful. The total volume of such trials (n=125) was 51.6%. Successful trials in this case were those in which the subjects found from 3 to 6 words (n=117); in total, they accounted for 48.4% of all trials. Similar trends were observed in certain abilities tests, where each level is determined by adding the number of problems solved, or points obtained.

Next, we compared the indicators of eye movements in the successful and unsuccessful samples. For the two groups with low and medium SL competence, we did not find any significant differences. However, some trends require reflection and further analysis. For instance, in the group with the lowest SL competence, we found that better results are associated with a longer scanning path (17238.32 vs 16228.52px; $F(1;285)=2.99$; $p<0.1$) and lower saccadic speed (88.94 vs 95.78deg/s; $F(1;285)=2.83$; $p<0.1$). In other words, the more elements of the matrix are scanned and the more slowly it is done, the more successful the word search and recognition are.

Table 6

Oculomotor parameters in high and low success trials in the group of experts

	Scan path Length (px)	**Fixation Duration Average(ms)**	**Saccade Duration Average(ms)**	**Saccade Amplitude Average(Bdeg)**	**Fixation/ Saccade Ratio**
Trials with low success level	20066.04	196.69	55.33	8.08	7.41
Trials with high success level	21875.59	215.06	35.86	5.11	9.08
F(1; 240)	7.1	10.22	10.88	9.21	4.43
Significance	p<0.01	p<0.01	p<0.01	p<0.01	p<0.05

Thus, successful word detection is linked with wider coverage of the search space. This strategy may be called "movement in breadth." Slower speed of movement along the matrix can be associated with higher awareness and control of the search process. In the group with medium language competence, the more successful trials were characterized by longer average fixation durations (225.03 vs

216.03ms; $F(1.267)=2.81$; $p<0.1$). Since average fixation duration is associated with the depth of processing, this may indicate that more successful word recognition is ensured by approaching semantic levels of information processing (Velichkovsky et al., 2005; Pannasch, Schulz, & Velichkovsky, 2011). This strategy can be described as "movement in depth."

In the group of experts, we found a number of significant differences in eye-movement indicators between successful and unsuccessful samples. The main results are presented in *Table 6*. Successful trials are characterized by a longer scan path and, at the same time, longer fixations and shorter saccades. Thus, the success in word search and recognition is determined, first, by larger coverage of the search space, and second, by deeper information processing. In other words, the integration of the two strategies identified earlier appears ("movement in breadth" and "movement in depth").

Conclusion

In this study, subjects were instructed to look for foreign language words in alphabetic matrices which were presented for 40 second intervals. The task turned out to be quite difficult: the subjects found an average of 1.53 words out of 10 (ranging from 0 to 6 in separate trials). The effects of word frequency, length, and orientation were discovered. The important thing was that the task successfully differentiated groups on the basis of their levels of foreign language competence.

Foreign language proficiency manifested itself both in search efficiency and in patterns of oculomotor activity. The increase in language competence resulted in an increase in the number of words found, regardless of the length and frequency of words. As for the eye-movement parameters, we observed several characteristic changes associated with the better knowledge of foreign language: 1) the overall length of the gaze path; 2) a rise in the number of oculomotor events and the average saccadic velocity and saccadic amplitude; and 3) a decrease in the average fixation duration. The data are consistent with those obtained in eye-movements studies on reading patterns in people with different levels of reading skill development.

The comparison of the more and less successful trials in groups with different levels of linguistic competence proved to be of interest. It turned out that success in task performance is associated with strategies of oculomotor activity. In the low competence group (novices), success was mostly determined by slower scanning speed, which presumably may indicate the use of more conscious strategies. In the group of users, there was a trend associating word search success with longer fixations, that is, with deeper semantic processing. The clearest differences between eye movements in successful and unsuccessful trials were observed in the group of the highest competence (experts). There were two significant and complementary trends. The word search success was achieved, first, by a longer gaze scan path, and second, by a focal mode of visual information processing, manifested in a combination of longer fixations and shorter saccades. Thus, we can draw the important conclusion that, even though enhancing linguistic competence leads to the development of faster and possibly automatic ways of verbal information processing, those subjects who chose to combine fast scanning with deep semantic processing proved to be more successful in the experimental task.

Limitations

Our research reveals some interesting trends in oculomotor activity with the growth of language competence, but all the participants were Russian learners of English. Significant distinctions in oculomotor activity patterns have been found in individuals who have mastered different writing systems. For example, Chinese and Hebrew native speakers' average saccade length was much shorter than that of English native speakers in reading English passages, due to the fact that linguistic information in these languages is more "densely packed" than in English (Pollatsek, Bolozky, Well, & Rayner, 1981). Thus, cross-cultural comparisons can be of great interest. Another aspect to consider is including a sample of English native speakers into the study, to evaluate how expert learners approach their eye movement patterns and word recognition models.

Moreover, the individual lexicon of each participant was not evaluated prior to the study. We assumed that the common word-frequency scale suited all the participants equally, although word familiarity can differ dramatically, depending upon a person's learning background, with beginning adult learners acquiring profession-specific vocabulary first. There is a possibility that commonly used words might have been unfamiliar to this group of respondents.

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Conceptualization of the Sensory Experience: A Frame-Based Approach

Georgiy B. Blinnikov*

Lomonosov Moscow State University, Moscow, Russia

*Corresponding author. Email: georgijblinnikov@gmail.com

Background. The search for reliable means of establishing relations between sensory qualia and their conceptualization in language has given rise to several approaches, both philosophical and psychophysical. This paper gives a short account of today's approaches to the problem and presents a frame-based approach, which may be superior to other methods.

Objective. To evaluate the effectiveness of the frame-based approach to the conceptualization of sensory qualia in language. The semantic field "Loud" in the Italian language is analyzed, as it offers a unique case: Italian does not have a lexeme whose main meaning would be translated into English as "loud" or into Russian as "громкий" (*gromkiĭ*).

Design. In the field "Loud", nine adjectives were analyzed by means of dictionary definitions, frequency in the Italian language corpus, and native speakers' usage.

Results. The findings reveal a frame structure of the field consisting of 11 frames, which can be grouped into two large entities: sounds proper and objects that emit sounds. The parameters that underpin the frame structure are vocal/non-vocal, intentional/spontaneous, explosive/non-explosive, one source/multiple sources, and natural/artificial. Another important result is a more accurate description of lexemes involved in the current field (the main adjectives are *alto*, *forte,* and *rumoroso*).

Conclusion. The frame-based approach provides an effective means of studying the relationship between sensory qualia and their conceptualization in language.

Keywords:
sensory experience, frame-based approach, conceptualization of qualia, corpora

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Introduction

The task of conceptualizing sensory experience has been undertaken by many sciences including psychology, linguistics, philosophy, and neuroscience. In a way, this problem was posed as early as the 17th century by John Locke, who postulated that the main source of knowledge about the world for man is experience. He wrote that our "understandings" are supplied with observation "employ'd either about external, sensible Objects; or about the internal Operations of our Minds" (Fuller, Stecker & Wright, 2000, p. 67). Despite a long history of debate and research, the question of how simple ideas generate complex ideas and how they are conceptualized remains unanswered. Russian psychology sees this type of process as a transformation of natural mental functions into higher ones. In the case of sensory experience, direct sensory sensations are transformed into concepts of qualities of the outside world. According to Lev Vygotsky (1978/1930), language tools play a crucial role in this transformation. However, an elegant principle of the development of higher mental functions confronts the problem of linguistic ineffability of sensory experience (Levinson & Majid, 2014).

Nowadays, philosophers reflecting on the nature of sensory experience usually employ the term *qualia* understood as "certain features of the bodily sensations especially, but also of certain perceptual experiences, which no amount of purely physical information includes" (Jackson, 1982, p. 273). Qualia are not physical characteristics of objects, but are part of the consciousness of the subject who perceives objects. On the one hand, they are reportable; on the other, they represent the world (Chalmers, 1996). However, by Dennett's definition, qualia cannot be directly reported from person to person; they can be experienced only because of one's own perception (Dennett, 1991). In fact, it has been shown that physical characteristics of the environment, subtly distinguishable by human sensory systems, cannot be differentiated easily by language (Agrillo & Roberson, 2009; Levinson & Majid, 2014).

But even if a sensory quality cannot be fully shared with others, people try to find language tools to convey at least some of its features. The need to share subjective sensory experience with another person leads to reflection and, eventually, to the categorization and conceptualization of this experience. It is not by chance that in a number of philosophical concepts, language is considered a kind of roadmap. L. Wittgenstein wrote that what one person sees and what the other sees when they perceive the color of an object may differ, but when both people associate this color with the word "red", certain similarities can be found in their sensations (Wittgenstein, 1953). Different points of view on linguistic ineffability and the possibilities of conceptualizing sensory experience prompt the search for new solutions of this problem.

We can identify three approaches to the relationship between sensory experience and language. Their common goal is to discover the connection between the world of sensations and the world of words, but their methodological frameworks differ considerably.

In the first approach, researchers study the naming of sensations. Subjects are offered a series of physical stimuli that they are to name; then their designations are analyzed. In their classic paper, B. Berlin and P. Kay (1969) found a correlation between the number of color terms in a language and what these terms should be. For example, if a language has only three terms for colors, they would be black (dark), white (light), and red. One hundred and ten unwritten languages were studied; their speakers were given chips of different colors which they were asked to name.

G. Senft, who studied color and taste terms in the Kilivila language spoken on one of the islands of Papua New Guinea, used color chips and containers with sour, bitter, sweet, or salty substances. Sixty subjects (between the ages of 4 and 75) were asked to name what they felt or saw (Senft, 1987). Eventually, the technique became widespread. In particular, some ethnographic and socio-anthropological studies employed the approach while investigating the sound landscape – i.e., how the audible environment is presented in different languages (Keil, Blau, Keil, & Feld, 2002).

These ethno-linguistic studies utilize the so-called quasi-psychophysical approach, which identifies language means used to denote sensory experience, and their limitations, making it possible to relate different zones of the sensory spectrum to their names. However, this methodology neglects many aspects of the conceptualization of sensory experience, notably the influence of culture and the specifics of the human activity. Not surprisingly, O. Le Guen, who examined the naming of color, texture, and other areas of sensory experience in languages of the Yucatan Indians, concluded that the sensory language is not influenced by material culture and reflects only the characteristics of sensory systems and tastes of the people (Le Guen, 2011).

The second approach is the study of the relationship between language and concepts. A renowned expert in the field of ethnography, Steven Tyler, believed that for comparing sensory systems in different cultures, psychophysical and psychophysiological knowledge is not of particular importance. Anthropologists and linguists can focus on studying differences between concepts that describe the world around them (Tyler, 1986). This approach is advocated by A. Wierzbicka and her followers. Adherents of this school are trying to identify a universal set of semantic primitives, or primes – that is, elementary words that exist in all languages. Using only the words from this set, one can, hypothetically, define any word in any language (Wierzbicka, 2010). The attempt to reduce general concepts to elementary sensations is promising, but it faces several difficulties. First, absolute synonyms are a rarity, and this certainly applies to equivalents in different languages; therefore, it is hardly possible to speak of a universal meta-language or a single lexical set for all languages, as the semantics of the units of the set are different in each language. The choice of primitives in some cases and the definition of individual words are also debatable.

The third, frame-based, approach could be seen as an alternative to the above-mentioned approaches. The basic idea of frame semantics, proposed by C.J. Fillmore (1977), is that word meanings are best described in terms of the schematization of events and objects, based on experience. Such a scheme, referred to as a semantic frame, includes the event, its participants and circumstances, and establishes links between them (cf. Ruppenhofer, Boas & Baker, 2017). Ideas of frame semantics were first put to the test in the systematic analysis of lexicons in English (Fontenelle, 1997; Heid, 1996), but similar projects were conducted later for Japanese (Ohara, 2015), German (Burchardt et al., 2009), Brazilian Portuguese (Salomão, Torrent, & Sampaio, 2013), Finnish (Lindén, Luukkonen, Laine, Roivainen,

& Väisänen, 2017), Italian (Luraghi, 2015), and French (Candito et al., 2014). In Russia, this approach has been developed by the Lexical Typology group headed by E. Rakhilina, although frame semantics here has been given its own interpretation (Rakhilina, 2016).

The object of research is the semantic field – i.e., a group of words with a single, integral semantic function, which represents a particular class of objects, phenomena or, as in our case, qualities of the outside world. In this framework, these are always synonymous lexemes, such as verbs that have a seme of movement (e.g., walking, running, swimming, rolling [Kobozeva, 2000; Kuznetsov, 1990]), a seme of temperature (Luraghi, 2015), a seme of a surface irregularity (Kashkin 2013), etc.). At first glance, the study of synonyms should yield rather poor semantic results; after all, the only thing that is interesting about lexemes with the same semantics is their existence and their quantity. However, as was shown by A. Apresyan (1995), absolute synonyms are very rare in a language. It would be correct to talk about quasi-synonyms and say that words are semantically similar rather than semantically identical. This allows us to compare a word with many other words and define their relative similarity. For the frame approach, it is crucial to identify contexts for which the use of one quasi-synonym is prototypical and the use of another quasi-synonym is restricted.

The frame acts as an invariant of certain contexts that are lexically opposed to other contexts. In the formal approach, it can be described as a situation that represents the outside world with a number of assigned syntactic roles. Rakhilina gives her own definition of the frame: It is a general situation that has fixed prototypical participants (Rakhilina & Reznikova, 2013). The identification of such situations is based on the compatibility of the lexemes under study with the surrounding context or, in other words, their ability to form certain collocations. For example, the semantic field of surface irregularities in the Italian language has such frames as “large, visually perceptible roughness”, denoted by the lexemes *ruvido* ‘rough’ and *scabro* ‘rough’, and “roughness and rigid structure of the object”, denoted only by the lexeme *ruvido* ‘rough’. Thus, the second frame is based on the use of *ruvido* and restriction on the use of *scabro*. It should be emphasized that it is the semantic restrictions on compatibility, not the morphosyntactic ones, which are relevant, as they make it possible to determine semantic differences between situations (frames).

The collocations that the lexemes form are determined by different methodological techniques: primarily the use of dictionaries, analysis of the frequency of collocations in language corpora, and surveys of native speakers. Each semantic field has a specific set of frames and a finite set of lexemes that denote these frames. The frame structure of the semantic field and its lexical structure are visualized in semantic maps.

The object of many studies is sensory vocabulary: qualities of smoothness and roughness of the surface (Blinnikov, 2013; Kashkin, 2013); temperature (Luraghi, 2015); tight and elastic qualities (Baskakova, 2015), and others. Papers on the metaphoric shifts between different sensory zones could also be mentioned (e.g., Blinnikov, 2015). Both the languages of one family (for example, the Uralic languages) and languages belonging to different families (Indo-European, Semitic, Kartvelian, and others) are studied.

Methods

Rationale and Method Applicability

The goal of this study is to analyze the semantic field of loudness above the norm ("Loud") in Italian. The basis of our work is the methodology employed by the Lexical Typology group; however, at one point our research is different. This group investigated a large number of languages belonging to different language families, whereas in the present case, the semantic field is studied only in one language (Italian), with Russian and English as background languages. Certainly, this study cannot claim to identify the universal frame structure of the field, but it still can provide meaningful results, because a significant area of the studied semantic field is covered by lexemes functioning in their metaphorical meaning. For example, the Italian language does not have a lexeme whose main meaning would be translated into English as "loud" or into Russian as "громкий" (*gromkiĭ*). The first consequence of this circumstance is the rich synonymy of lexemes in this field. This is predictable, as the metaphorical meaning depends on both the properties of the source zone and those of the target zone (Lakoff & Johnson, 2008). As the sounds differ in many parameters (to be described below), the metaphorical meanings of one or two lexemes are incapable of including the whole multitude of such parameters. Hence we can deduce a second consequence: The need to fill the field with lexemes in their figurative meaning activates the semantic field parameters that exist implicitly in the human mental world, but are not expressed in language systems with lexemes denoting a high degree of loudness in their nominative meaning. Such parameters can potentially be detected in other languages. However, even if some qualities can be found only in the Italian language, it is noteworthy that they, and not others, are reflected in the language that experiences this kind of lexical "famine".

Research Design

The first step in our research is to define the boundaries of the studied semantic field. Initially, the field boundaries are based on the native language vocabulary, but when moving to other languages, these boundaries can shift significantly (Rakhilina & Prokofieva, 2004).

The next step is a search for translation equivalents of the initial lexemes in ***bilingual dictionaries***. The obtained list of words is verified via ***text corpora***. Corpus contexts in which these lexemes are used are compared to each other within the same language and undergo semantic analysis, which reveals parameters by which these contexts differ. The Sketch Engine was used as the Italian text corpus (Kilgarriff, 2014). It consists of written texts (both literary and journalistic) representing the modern Italian language, and contains 2.5 billion word tokens. It is the largest corpus of the Italian language today and can be considered representative for the purposes of this research.

In the next step, these data help compile questionnaires for native speakers. The survey was conducted on a ***sample of speakers*** of the Italian language who were studying linguistics in Italian universities or had a scientific degree in linguistics (20 people in total; 7 males, 13 females; the average age of subjects was 35.2 years).

Subjects were selected based on their origin: The south, center, and north of the country were evenly represented. Subjects provided information about themselves: surname, first name, gender, age, place of birth, and education. The questionnaire included a list of adjectives from the semantic field and a number of sentences with omissions that the subjects were asked to fill in. The sentences were of the following type: *Ieri si poteva sentire la musica ... dalla sua casa. I vicini non possono dormire.* "Yesterday ... music played in his house. Neighbors could not get to sleep." Subjects were asked to select one or more adjectives from the list to fill in the gaps. If none of the adjectives was suitable, subjects were allowed to suggest their own word which, in their opinion, better fit the context or to leave the gap blank if no word seemed appropriate to them.

Results

Our inquiry revealed two types of frames. Type A includes phenomena of a fully or partially acoustic nature (for example, a song, a voice, or a noise) that in Russian are denoted by the adjective *loud*; Type B includes objects that make sounds louder than the norm (a company of people, a waterfall, a street), i.e., that create a loud noise. In Russian, nouns denoting these concepts are collocated with the adjective *shumnyĭ* 'noisy'. In English, some of them are described by the adjective *noisy*, while others are denoted by the adjective *loud*.

Dictionary Analysis

The sample includes a total of nine adjectives: *forte* 'strong', *alto* 'high', *sonoro* 'sonorous', *sonante* 'sonorous', *rumoroso* 'noisy', *fragoroso* 'uproarious', *chiassoso* 'noisy, rowdy', *clamoroso* 'resounding, noisy', *assordante* 'deafening'. The final list contains the nouns that denote acoustic phenomena or objects emitting sounds, whereas their collocations with the studied adjectives generate significant phenomena. Thus these nouns either form a large number of collocations with one or several adjectives, or, contrary to the initial hypotheses, do not form any meaningful number of collocations (e.g., *radio* 'radio'). In other words, the final list includes nouns that correspond to the frames. The following nouns entered the final list: *voce* 'voice', *grido* 'shout, scream', *musica* 'music', *risata* 'laughter', *rumore* 'noise', *battito* 'knock', *applausi* 'applause', *discorso* 'speech' , *conversazione* 'conversation', *ambiente* 'environment', *via* 'street', *sala* 'hall', *cascata* 'waterfall', *compagnia* 'company (of people)', *gruppo* 'group (of people)', *bambino* 'child', *radio* 'radio', *sveglia* 'alarm', *motore* 'engine'.

The nouns listed above fall into two groups. Type A includes the following frames (nouns representing them are given in parentheses):

1. Vocal, intentional sounds (*voce* 'voice, *grido* 'shout, scream');
2. Intentional non-vocal sounds (*musica* 'music');
3. Vocal, spontaneous, explosive sounds (*risata* 'laughter');
4. Spontaneous, non-vocal sounds (*rumore* 'noise, *battito* 'knock');
5. Explosive, non-vocal sounds (*applausi* 'applause');
6. Vocal interaction (*discorso* 'speech', *conversazione* 'conversation').

Type B includes the following frames (nouns representing them are given in parentheses):

1. Locations (*ambiente* 'environment', *via* 'street', *sala* 'hall');
2. Objects that emit explosive sounds (*cascata* 'waterfall');
3. People (*compagnia* 'company (of people)', *gruppo* 'group (of people)', *bambino* 'child');
4. Sound devices (*radio* 'radio', *sveglia* 'alarm');
5. Noisy machinery (*motore* 'engine').

Corpora Analysis

The analysis of the text corpora yielded the following results (see Tables 1 and 2). The adjective *forte* 'strong' collocates with all the nouns of Type A (acoustic objects/phenomena; 1,377 collocations in total), except for the lexeme *conversazione* 'conversation'. When used with the noun *discorso* 'speech', it is used in the figurative meaning 'able to produce a powerful effect on the listener'. We find the largest number of collocations in the frame "Vocal, intentional sounds" (809 hits).

The adjective *alto* 'high' collocates with almost all the Type A nouns, with the exception of the noun *conversazione* 'conversation'. When used with the noun *discorso* 'speech', it is used in its figurative meaning 'lofty'. However, only interaction

Table 1

Corpus frequency of collocations of field adjectives with nouns denoting acoustic phenomena (Type A)

	Groups of nouns								
Adjective	***Suono* 'Sound'**	**Vocal, intentional sounds**	**Intentional sounds**	**Vocal, spontaneous, explosive sounds**	**Spontaneous sounds**	**Explosive sounds**	**Vocal interaction**	**Total**	**%**
Forte	142	809	76	22	247	21	60	1,377	15.09
Alto	64	5,229	268	1	9	1	66	5,638	61.77
Sonoro	8	92	1	80	8	6	30	225	2.47
Sonante	1	10	0	4	0	1	1	17	0.19
Rumoroso	17	3	28	20	4	1	4	77	0.84
Fragoroso	14	6	12	211	37	161	2	443	4.85
Chiassoso	6	20	5	5	2	0	1	39	0.43
Clamoroso	1	14	0	14	0	1	2	32	0.35
Assordante	100	55	293	5	813	12	1	1,279	14.01
Total	353	6,238	683	362	1,120	204	167	9,127	100
%	3.87	68.35	7.48	3.97	12.27	2.23	1.83	100	–

Note: Each cell shows the number of collocations for the given adjective (in the left column) and the given group of nouns (column head).

Table 2

Corpus frequency of collocations of field adjectives with nouns denoting objects that emit sounds (Type B)

Adjective	Groups of nouns						
	Locations	**Objects that emit explosive sounds**	**People**	**Sound devices**	**Noisy machinery**	**Total**	**%**
Forte	N/A	N/A	N/A	5	N/A	5	0.75
Alto	I/M	I/M	I/M	8	I/M	8	1.19
Sonoro	290	3	5	2	17	317	47.31
Sonante	1	0	1	0	0	2	0.31
Rumoroso	150	1	29	1	48	229	34.18
Fragoroso	0	21	2	0	0	23	3.43
Chiassoso	12	0	62	0	0	74	11.04
Clamoroso	1	0	0	0	0	1	0.15
Assordante	4	4	0	1	2	11	1.64
Total	458	29	99	17	67	670	100
%	68.36	4.33	14.78	2.53	10	100	–

Notes. Each cell shows the number of collocations for the given adjective (in the left column) and the given noun (column head). N/A = not applicable; I/M = improper meaning.

with the noun *suono* 'sound' (64 hits) and the frames "Vocal, intentional sounds" (5,229 hits) and "Intentional sounds" (268 hits) can be recognized as significant. Despite an extremely large number of references to the collocation of the adjective *alto* 'high' with *voce* 'voice' ("Vocal, intentional sounds"), the overwhelming part of them is the collocation *a voce alta* 'in a loud voice', 'aloud' (the synonym *ad alta voce* has 11,127 hits).

The largest number of collocations with the lexeme *sonoro* 'sonorous' are found in the frames "Vocal, intentional sounds" (92 hits) and "Vocal, spontaneous, explosive sounds" (80 hits). With the rest of the stimuli, collocations are few (the word *suono* 'sound', "Intentional sounds", "Spontaneous sounds", "Explosive sounds") or the adjective is used in the meaning 'acoustic' (noun *discorso* 'speech' and all the Type B nouns).

Among the adjectives under scrutiny, *sonante* 'sonorous' is the least used. The lexeme *rumoroso* 'noisy' collocates with both Type A and Type B. However, there are fewer collocations with the Type A nouns compared to Type B (77 hits against 229 hits). In Type A, it predominantly collocates with the frames "Vocal, spontaneous, explosive sounds" (20 hits) and "Intentional sounds" (28 hits). In Type B, 150 collocations were in the frame "Locations", 29 collocations in the frame "People", and 48 collocations in the frame "Noisy machinery". Only one collocation was found in the frame “Sound devices” (with the noun *radio* ‘radio’) and one collocation in the frame “Objects that emit explosive noises”.

The adjective *fragoroso* ‘uproarious’ collocates mainly with the Type A nouns (443 hits in total); in Type B, we found only 23 collocations (21 of them with one noun). The lexeme actively interacts with the frames “Vocal, spontaneous, explosive sounds” (211 hits), “Explosive sounds” (161 hits), and “Objects that emit explosive sounds” (21 hits).

The adjective *chiassoso* ‘noisy, rowdy’ mainly collocates with the frame “People” (62 hits) and the frame “Vocal, intentional sounds” (20 hits).

The number of collocations with *clamoroso* ‘resounding, noisy’ and stimuli was insignificant — with the exception of the frames “Vocal, intentional sounds” (14 units) and “Vocal, spontaneous, explosive sounds” (14 units). However, in the frame “Vocal, intentional sounds”, the adjective is used in its metaphorical meaning: The collocation *voce clamorosa* means ‘scandalous rumor’.

The lexeme *assordante* ‘deafening’ actively interacts with Type A (1,279 collocations) and almost does not interact with Type B (11 collocations).

The analysis confirms the rare usage of the adjectives *sonante* ‘sonorous’ and *clamoroso* ‘resounding, noisy’. *Alto* ‘high’, *forte* ‘strong’, and *assordante* ‘deafening’ are the primary adjectives that collocate with the frames of Type A.

Survey of Native Italian Speakers

Analysis of the questionnaires revealed the following:

About a permanent voice quality which communicates that its owner is in the house (Voce): 60% *forte* ‘strong’, 15% *alto* ‘high’, 15% “Other”, *assordante* ‘deafening’ 10%. The category “Other” comprises the adjectives *tonante* ‘thunderous’ and *squillante* ‘resonant’.

About a high-pitched voice (Voce): 70% “Other” (adjectives *acuto* ‘shrill’, *squillante* ‘resonant’), 30% *alto* ‘high’;

In the fixed phrase ‘in a loud voice’ (‘aloud’) (Voce): 100% *alto* ‘high’;

About a piercing voice that makes the ears ring (Voce): 65% “Other” (*stridulo* ‘sharp’, *acuto* ‘shrill’, *squillante* ‘ringing’, 30% *assordante* ‘deafening’, 5% *clamoroso* ‘resounding, noisy’);

About a sound louder than the norm (Suono): 70% *alto* ‘high’, 20% *forte* ‘strong’, 5% *assordante* ‘deafening’, 5% “Other” (*acuto* ‘shrill’);

About deafening sounds (Suoni): 50% *assordante* ‘deafening’, 20% *forte* ‘strong’, 20% “Other” (*acuto* ‘shrill’), 10% *alto* ‘high’;

About music that keeps you from sleeping (Musica): 60% *alto* ‘high’, 40% *forte* ‘strong’;

About loud laughter (Risata): 85% *fragoroso* ‘uproarious’, 5% *forte* ‘strong’, 5% *assordante* ‘deafening’, 5% “Other” (*dirompente* ‘explosive’);

About laughter that sounds like the ringing of a bell (Riso): 90% “Other” (*squillante* ‘ringing’, *stridulo* ‘sharp’), 5% *sonoro* ‘sonorous’, 5% *chiassoso* ‘noisy, rowdy’;

About a hall with good acoustics (Sala): 95% “Other” (subjects were undecided), 5% *sonoro* ‘sonorous’;

About a noisy urban environment (Ambiente): 95% *rumoroso* ‘noisy’, 5% *assordante* ‘deafening’;

About loud applause (Applausi): 80% *fragoroso* ‘uproarious’, 10% *clamoroso* ‘resounding, noisy’, 10% “Other” (*scrosciante* ‘thunderous’);

About a loud company (Comitiva): 60% *chiassoso* 'noisy, rowdy', 40% *rumoroso* 'noisy';

About a child who is too loud (Bambino): 50% *rumoroso* 'noisy', 35% *chiassoso* 'noisy, rowdy', 10% *assordante* 'deafening', 5% "Other" (subjects were undecided);

About a waterfall that produces a noise so loud that people cannot hear each other talk (Cascata): 70% *rumoroso* 'noisy', 20% *fragoroso* 'uproarious', 10% *assordante* 'deafening';

About a square filled with people (Piazza): 35% *rumoroso* 'noisy', 35% *chiassoso* 'noisy, rowdy', 20% "Other" (*caotico* 'chaotic', some subjects were undecided), 10% *assordante* 'deafening';

About a radio that is too loud (Radio): 50% *alto* 'high', 25% "Other" (subjects were undecided), 15% *forte* 'strong', 10% *rumoroso* 'noisy';

About an alarm clock that wakes up the whole house (Sveglia): 20% "Other" (*fastidioso* 'annoying', *penetrante* 'penetrating', some subjects were undecided), 35% *assordante* 'deafening', 20% *rumoroso* 'noisy', 15% *chiassoso* 'noisy, rowdy', 5 % *alto* 'high', 5% *forte* 'strong'.

The main adjectives that collocate with the Type A nouns are *alto* 'high' and *forte* 'strong'. The main adjective that collocates with the Type B nouns is *rumoroso* 'noisy'. Nouns denoting a person or a group of people also collocate with the adjective *chiassoso* 'noisy, rowdy'. The adjective *sonoro* 'sonorous' hypothetically can collocate with the noun *sala* 'hall' in the meaning 'a hall with good acoustics' (*sala sonora*). Collocations in the frame "Sound devices" (*radio* 'radio' and *sveglia* 'alarm') were found to be unstable: Subjects named adjectives usually used with the Type A nouns (in this case we are dealing with a metonymic shift from the sound produced by the device to the device itself) and also adjectives usually used with the Type B nouns. Some subjects noted that the use of adjectives with these nouns is incorrect.

In the context of overly loud sound, subjects selected *alto* 'high' and *forte* 'strong' in addition to the basic adjective *assordante* 'deafening'. Some subjects suggested the adjective *assordante* 'deafening' in other contexts when they thought that the sound was too loud.

Generally, the subjects' answers confirmed the patterns found in the corpus analysis of collocations.

Discussion

The difference between Type A and Type B is shown in Figure 1.

Type A and Type B reveal semantic oppositions which form the basis for the conceptualization of loudness perception. Two categories emerge: sounds proper and objects that emit sounds. In the first category, intentional sounds are opposed to random sounds (subjects' intentions); explosive sounds are opposed to smooth sounds (sound properties); and vocal sounds are opposed to the rest (means of sound production). The second category includes oppositions between the natural and the artificial. The natural is subdivided into locations (a square or a street), natural objects (a waterfall), and people (a woman or a child). The artificial has two subcategories: mechanisms created to produce sounds (a radio or TV set) and mechanisms producing sounds as a side effect (an engine). The frame structure is shown on the semantic map (see *Fig. 2*).

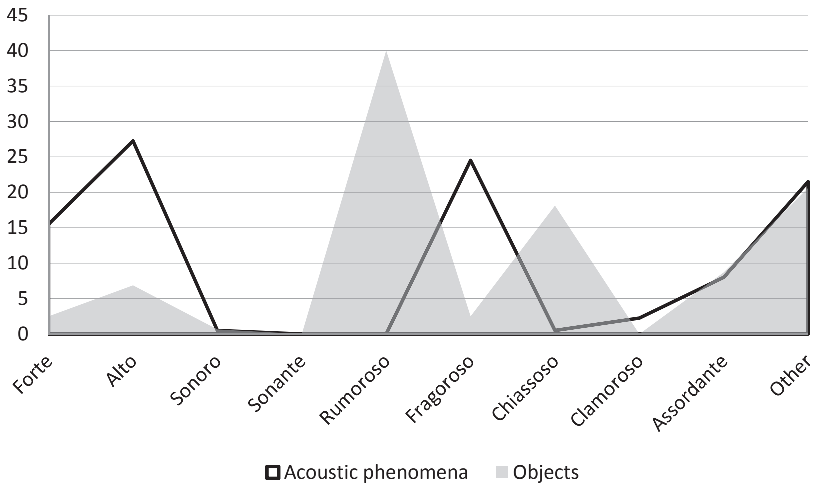

Figure 1. Subjects' responses to the questionnaire.

Note: Frequency (%) of usage of the field adjectives in frames related to acoustic phenomena (black & white) and frames related to objects that emit sounds (grey).

The frame-based analysis is also a powerful instrument to study the semantics of individual words. Two lexemes forte 'strong' and alto 'high' are of special importance, as they are, on the one hand, the main designators of the Type A frames (acoustic phenomena) and, on the other, are used in their figurative meaning.

The first meaning of the Italian word *forte* is 'strong'. A similar meaning is found in the Russian collocation *sil'nyĭ shum* 'strong noise' (i.e., 'loud'). The English collocation *strong voice* could be interpreted as 'loud voice', as well, if we consider the first meaning of the word *voice* ("the sounds that someone makes when they speak" [Rundell, 2012]).

Such collocations are possible due to the fact that the word *strong* intensifies the quality of an object with which it collocates (or more precisely a noun that it denotes). The range of concepts that *strong* can intensify varies in different languages, but obviously this lexeme has this potential. Having no lexeme whose nominative meaning would be an increased or noticeable loudness (Latin also lacked such a word), the language employs a lexeme potentially capable of "intensifying" any attribute and of entering a wide range of collocations (according to the *Treccani* Italian dictionary [Duro, 2008], *forte* 'strong' has nine meanings). Another factor contributing to the emergence of a new meaning is the correlation between intensification of a process and increase in loudness of the accompanying sound. This works for such processes as laughing or coughing: The more energy one uses, the louder these processes are — hence such collocations as *risata forte* 'strong laughter' and *tosse forte* 'strong cough'. Certainly, collocation restrictions are imposed even when *forte* 'strong' is used in its first meaning. For example, *forte rissa* 'strong fight' is most likely impossible.

When *forte* means 'loud', it cannot collocate with the Type B nouns (objects and people making noise; locations filled with noise): *compagnia forte* 'strong company', *via forte* 'strong street', *motore forte* 'strong engine'. This is partly because the adjective *forte* 'strong' is not a full-fledged sound lexeme; its meaning "loud"

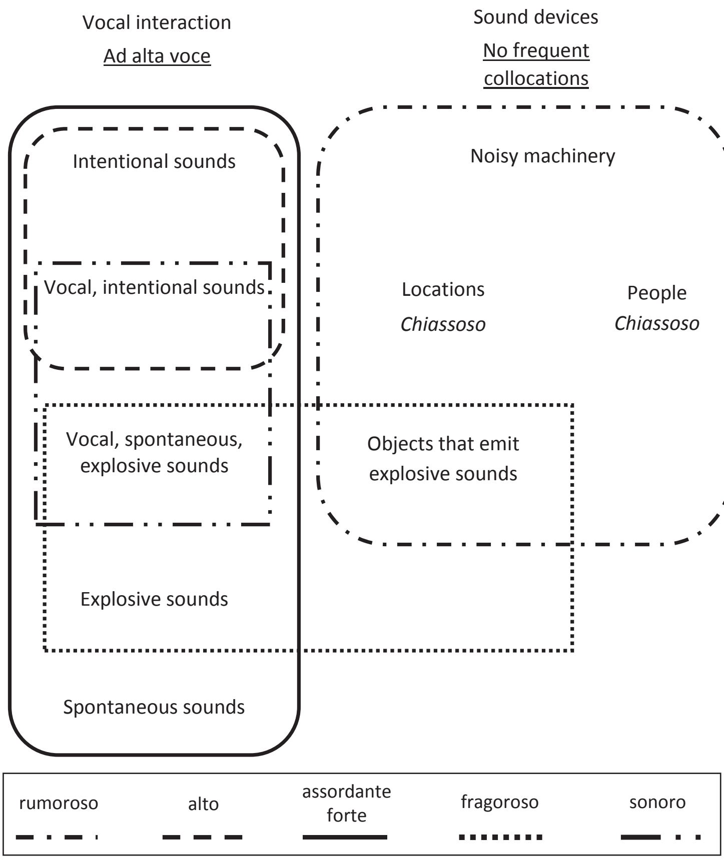

Figure 2. Semantic map of the field "Loud".

Note: The map contains 11 frames and five zones which show the distribution of lexemes in the field. The frames covered by chiassoso are marked with the word "chiassoso". The expression "ad alta voce" (in the frame "Vocal interaction") is underlined, as it is not part of the subject of research. No frequent collocations were found for the frame "Sound devices" (underlined on the map).

is metaphorical and therefore it cannot, for example, be a source for metonymic shifts. Metaphorical shifts with the meaning "loud" as the source for the metaphor are also restricted.

Alto (literally, 'high') is one of the main lexemes (along with *forte* 'strong') to denote loudness above the norm of Type A. However, while the typical collocations of *forte* 'strong' include almost all the nouns of this type, *alto* 'high' makes typical collocations only with the nouns that denote targeted acoustic phenomena: *voce* 'voice', *grido* 'shout, scream', *musica* 'music'. It can also collocate with the word *suono* 'sound'. Nouns denoting sounds that are usually spontaneous and do not have a target (e.g., *rumore* 'noise', *battito* 'knock', *risata* 'laughter') are unlikely to form collocations with *alto* 'high'. A related property of these sounds, which hypothetically makes them (or more specifically the nouns denoting them) unsuitable for collocations with *alto* 'high', is their brevity. As the meaning of loudness above the norm of *alto* 'high' is metaphorical, its use in metonymic shifts is also complicated. Thus it does not usually collocate with the Type B nouns.

Other lexemes which are used for the Type A frames are *sonoro* and *sonante*, both denoting an intensive sound vibration ('ringing, sonorous'); however, *sonante* 'sonorous' is much less frequent, and *assordante* 'deafening' denotes an extreme level of loudness. *Fragoroso* 'uproarious' may cover the frames of both Type A and Type B: "Explosive noise", "Vocal, spontaneous, explosive sounds", "Explosive sounds". As seen from the names of the frames, the principal quality that this word denotes is explosiveness – hence such widespread collocations as *cascata fragorosa* 'deafening waterfall' and *risata fragorosa* 'uproarious burst of laughter'. *Rumoroso* 'noisy' is the main adjective for the Type B frames: "Locations", "Objects that emit explosive sounds", "People", "Noisy machinery". The meaning of the lexeme can be described as "making (extra) noise". The meaning is rather loose, deprived of shades of meaning proper to its quasi-synonyms *fragoroso* 'uproarious' and *chiassoso* 'noisy, rowdy'. *Chiassoso* 'noisy, rowdy' is used mostly with nouns denoting people (frame "People") or places with people (frame "Locations"). *Clamoroso* 'resounding, noisy' was found to collocate poorly with the stimuli and thus can be considered irrelevant for this field.

We notice that some physical characteristics tend to fuse: For example, the sensation of loudness is connected to such dynamic properties of a sound event as smoothness and explosiveness. This is also reflected in the new environmental psychophysics, which treats a perceived quality as a fusion of individual sensory qualities (Nosulenko & Samoïlenko, 2013, 2016).

Conclusion

The frame-based approach provides an effective means of studying the relationship between sensory qualia and their conceptualization in language. Frames serve as an intermediary link between the outside world and language, as situations that they denote, on the one hand, describe reality and, on the other, are defined by language.

The frame structure given in this study reflects a complex conceptual system of representations of the properties of sound phenomena. Primarily, language registers a substantial difference between characteristics of sounds proper (Type A) and characteristics of objects that emit sounds (Type B). Analysis of the field also showed the importance of such sound features as vocal/non-vocal, intentional/spontaneous, explosive/non-explosive, one source/multiple sources. For objects and processes that emit sounds, their taxonomic class gains relevance (natural vs. artificial). The meanings of the Italian lexemes used to denote the qualities of the field (roughly corresponding to the English words *loud* and *noisy*) were specified.

These data can be seen as a contribution to the theory of object-relatedness of sensory experience (Barabanshchikov, 2019; Nosulenko, 2016). The loudness of a speech sound and the loudness of a closing door are assumed to represent different qualities, even when the sound wave amplitude of both sounds is the same. This is partially confirmed in psychophysical research (Huang & Elhilali, 2017; Nosulenko & Samoïlenko, 2016).

The opposition found in this paper could be compared to the one that has emerged in the philosophical debate of recent years. According to one point of view, auditory experience is treated as sensations born in mind and detached from objects or phenomena that emit them (Maclachlan, 1989). Another point of view states that sounds are closely connected both to the outer world and to objects that emit them (O'Callaghan, 2014). Our findings show that not only sounds, but also their individual qualities, are distally located, event-like, and semantic phenomena.

We do not assert that the experience of sensory qualities is equal to their verbal designation. However, psychologists who analyze perception of the naturally sounding environment isolate perceived qualities on the basis of their verbal descriptions (Nosulenko & Samoĭlenko, 2013). Classification of sounds and their qualities influences the perception and the experience of them: The loudness of intentional sounds is not equal to the loudness of spontaneous sounds, and noisy people are different from noisy mechanisms. The following explanation could be given: The experience of loudness is embedded in the global process of perception of the world, which is provided not only by sensory systems, but also by the knowledge stored in mental structures, representing past perceptual and mental experience.

Limitations

As the current paper investigates the field "Loud" only in one language, its results are, strictly speaking, relevant only for Italian. Although the findings could be seen as the basis for studying human cognitive structures, research on other languages is crucial for arriving at a well-grounded conclusion. Another limitation is the number of native speakers interrogated for the survey; more subjects will make the sample more representative. Another possibility for future research is to survey native speakers who are not trained in linguistics. Comparison between informed opinions of specialists and opinions based only on one's linguistic feeling could be of interest.

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Comparing the Generation of Words from Different Semantic Categories in Native and Foreign Languages

Olga P. Marchenko*

Moscow State University of Psychology and Education, Moscow, Russia

* Corresponding author. E-mail: olga.p.marchenko@gmail.com

Objective. The aim of this study was to evaluate the degree of conformity of generation frequency scores for semantic categories between native (L1) and foreign languages (L2).

Design. Sixty-eight native Russian-speaking students were asked to list words belonging to different semantic categories in the Russian and English languages. Their generation frequency was calculated for each word in both languages. Hellinger Affinity scores were used to measure the conformity of the generation frequency norms between the Russian and English language.

Results. For culture-dependent categories, the level of conformity between the category frequencies in the Russian and English languages was greater than the conformity with North American norms. For culture-independent categories there were no significant differences in the level of conformity between the native and foreign languages as compared with North American frequencies. Furthermore, the number of concepts with significantly different levels of frequency between the Russian and English language was greater for culture-dependent categories than for culture independent-categories.

Conclusion. The low level of similarity for some categories can be explained by the subjects' different levels of experience using native and foreign languages in the context of these categories. A low level of category frequency accordance can be also explained by the fact that when subjects switch to a foreign language, they tend to name the concepts which are representative of the culture of this language. The strong level of similarity for other categories suggests that the vocabulary of these categories is less affected by cross-cultural and cross-linguistic diversity.

Keywords:
category norms, exemplar generation frequency, cross-language difference, Russian language, English language, L1, L2, Hellinger Affinity coefficient

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Introduction

The study of semantic categorization is one of the central problems being studied in cognitive psychology. Given that culture and conceptual behavior are tightly related, such questions need to be studied in the context of culture (Ojalehto & Medin, 2014). Cultural differences can be manifested in how semantic information is organized and used in tasks requiring categorization. One of the simplest and most widely available methods in the study of the features of categorization and organization of knowledge in long-term memory, is the method of generating items belonging to a particular category within a certain time interval (Voorspoels et al., 2013). This technique allows one to determine the content and structure of categories. For diagnostic purposes, one can determine the so-called category fluency (number of words in a category named during a certain period of time). Not only the category fluency but also the frequency of the naming of certain words in the category (generation frequency) is of particular interest.

Today, language is typically considered a part of culture. Language and other elements of culture do not act in isolation from each other, but are related by mutual influence and mutual reinforcement. Fixation on important cultural patterns in a language ensures its longevity and universality for all members of a given society (universal distribution within the culture). This is because the process of language acquisition automatically becomes the process by which person turns into a full member of that culture (Fausey et al., 2010). Therefore, the results of studies of bi-cultural individuals, in which it has been shown that a person changes his/her behavior after switching from one language to another, are quite understandable. Language, being a conductor of culture, can influence memory, thinking, self-esteem, and/or personality traits (Marian & Kaushanskaya, 2004; Oyserman et al., 2008; Ramírez-Esparza et al., 2006).

Category frequency and the richness of vocabulary in the designation of certain concepts (the "dictionary development" of the language) can be key indicators of the specific traits of different cultures (Wierzbicka, 2001). The most typical items within categories often coincide in different cultures (Yoon et al., 2004; Pekkala et al., 2009). However, along with the similarity of categories' content in different languages, there are also significant qualitative and quantitative differences caused by cultural factors (Pekkala et al., 2009; Eng et al., 2018). Cultural differences in categories' content and category fluency can be caused by many factors, such as differences in social, historical, economic, and educational systems; habitat; the degree of the population's familiarity with the category; as well as by purely linguistic factors such as word length (Pekkala et al., 2009).

The problem of inter-cultural stability and the diversity of categories naturally leads to the question of how bilinguals use categories. Bilinguals are worse than monolinguals in performing the categorical fluency task and demonstrate a smaller vocabulary even in their first language (Bialystok et al., 2008). Moreover, when bilinguals are tested, significant differences in the performance of a category fluency task in their native and foreign language may be found for some categories, while for other categories, their results are roughly the same (Ardila & Bernal, 2006; Grogan et al., 2009).

These results can be explained by two factors. First, the experience of interaction with objects from different categories may differ in the context of L1 and L2 usage. For example, it has been shown that emotional concepts in L2 do not evoke an emotional response (Pavlenko, 2012). Second, as explicated above, there may be some categories that are cross-culturally very stable, and other categories that are culturally specific. What's important is that the differences in the conceptual structures associated with L1 and L2 should be reflected in the differences in the structure of the categories when the subjects are tested in L1 and L2.

Empirically, the difference in the structure of a category in L1 and L2 can be operationalized by studying the similarity between the distributions of generation frequencies obtained for this category in L1 and L2. The similarity between the two frequency distributions can be computed by a number of means, one of which is the widely-used Hellinger Affinity (HA) coefficient (Yoon et al., 2004). Thus, the purpose of this study was to compare generation frequencies for different semantic categories generated for L1 and L2. Specifically, we computed HA scores for a number of categories reflecting the similarity (proximity) of generation frequency distributions obtained for these categories in L1 and L2. We expected that for some categories, the similarity measures would be greater than those for other categories, since a foreign language is used differently in different areas of human activity. In addition, we analyzed to what extent the categories' structures obtained for L1 and L2 were similar to the normative structures of these categories, as exhibited by native speakers of L2. This would allow us to show whether an individual starts to use a foreign language's conceptual structure when switching to L2.

Method

Sample

Sixty-eight students from the Moscow State Linguistic University, aged 18-27 years (58 women and 10 men, M=20.5, SD=2.2), participated in the study. All were native Russian speakers who had experience in learning English.

Procedure

The procedure used to obtain the categorical frequency scores was identical to the procedure developed by F.W. Battig and W.E. Montague (Battig & Montague, 1969). Participants received small notebooks in which they had to list items belonging to different categories. The experimenter read the instructions aloud and named the categories. Participants were asked to list as many items belonging to a category as they could in 30 seconds. In order to obtain a reliable result in computing the proximities between categories' structures, it was necessary to use a large number of different categories for testing (in many contemporary studies only one or just a few categories are used).

All participants performed the category fluency task in Russian (L1) and in English (L2). The order of languages was counterbalanced across participants. The category names were presented randomly to different groups of participants. The random order for both the native and foreign language was the same. Forty-five semantic categories of various types were selected (*Fruits, Fish, Insects, Vehicles, Furniture, etc.*). The frequency of each word in a category for Russian and English was calculated.

The similarity of frequency distributions

In order to measure the similarity (proximity) of the frequency distributions for each category between Russian and English, the Hellinger Affinity (HA) coefficients were used (Yoon et al., 2004). HA is calculated by summing the square root of the product of the two items' frequencies (p_i, q_i):

$$\mathrm{HA}(p, q) = \sum \sqrt{p_i q_i}$$

The value of Hellinger Affinity coefficients ranges from 0 to 1, with 1 meaning that two frequency distributions are identical.

The median number of words named in each category in 30 seconds was measured. The median number of named words in Russian and English and their HA scores were then compared using the Wilcoxon T-Test. For each word, overall generation frequencies were compared between L1 and L2, with the help of Pearson's χ^2-test with Yates' correction for continuity. The number of significant differences ($p<0.01$) was compared between regions, using the one-tailed Pearson χ^2-test as well. The HA scores between L1, L2, and North American norms were compared using the Friedman and T-Wilcoxon tests. North American generation frequency norms for 36 categories in English language were taken from Van Overschelde et al. (2004). Intra-cultural HA scores for Russian generation frequencies were taken from Marchenko et al. (2018).

Results and Discussion

The average number of words named in L2 in 30 seconds for a category was less than the number of words named in L1 (6.56 ± 2.8 vs. 4.27 ± 2.8, $Z=-5.744$, $p<0.001$). Such differences can be explained by the fact that the size of a person's vocabulary is significantly smaller in a foreign language than in his/her native language. In addition, it was suggested that the naming speed in the L2 might be reduced because a person's ability to express knowledge in a foreign language is not as automatic as it is in his/her native language. The ease and speed of access to a lexicon depend upon the age of acquisition, frequency, and recency of access (Snodgrass & Tsivkin, 1995).

It has also been observed that even balanced bilinguals (these who have approximately similar experience using both languages in different areas of human activity), then using their dominant language, perform worse on the category fluency task than monolinguals (Bialystok et al., 2008). There are several explanations for this deficit. Perhaps bilinguals cannot suppress interference which is caused by the activation of another language. Perhaps in bilinguals, each language is supported by weaker ties connecting concepts with words, as compared to monolinguals who use only one language (Bialystok et al., 2008). In addition, if the word is activated in Russian at the first moment of the task performance, and it has to be translated into a foreign language, then it takes more time to name the word in English than when the task is performed in the native language.

Hellinger's Affinity coefficients between the frequency distributions of words generated for all categories in English and in Russian are presented in *Table 1*.

Table 1

Hellinger's Affinity scores for category frequency distributions in L1, L2, North American category norms, and Russian category norms.

	Hellinger's Affinity					
Category	**L1&L2**	**L2&NA**	**L1&NA**	**RN1**	**RN2**	**RN3**
Alcoholic Beverages	0.91	0.83	0.76	0.97	0.95	0.96
Amphibians	0.90	–	–	0.93	0.91	0.92
Birds	0.75	0.61	0.63	0.96	0.95	0.97
Body Organs	0.78	–	–	0.97	0.96	0.95
Body Parts	0.88	0.92	0.87	0.96	0.96	0.96
Furniture	0.84	0.68	0.74	0.96	0.96	0.96
Carpenter`s Tools	0.73	0.66	0.70	0.92	0.92	0.92
Clothing	0.83	0.76	0.75	0.96	0.95	0.96
Colors	0.92	0.94	0.91	0.98	0.98	0.98
Countries	0.90	0.79	0.73	0.95	0.95	0.95
Crimes	0.58	0.68	0.75	0.91	0.90	0.91
Diseases	0.53	0.46	0.57	0.91	0.91	0.91
Distance Units	0.89	0.93	0.85	0.97	0.97	0.96
Domestic Animals	0.91	–	–	0.96	0.95	0.97
Domestic Appliances	0.82	–	–	0.96	0.94	0.95
Fabrics	0.86	0.76	0.79	0.94	0.94	0.93
Family Members	0.90	0.92	0.86	0.98	0.98	0.98
Farm Animals	0.91	–	–	0.98	0.98	0.98
Female Names	0.50	0.33	0.04	0.91	0.93	0.91
Fish	0.51	0.60	0.64	0.91	0.84	0.87
Flowers	0.72	0.63	0.67	0.95	0.91	0.92
Foods	0.68	–	–	0.89	0.89	0.89
Four-footed Animals	0.89	0.90	0.81	0.96	0.96	0.96
Fruits	0.91	0.92	0.89	0.98	0.97	0.97
Insects	0.82	0.86	0.87	0.96	0.96	0.96
Kitchen Utensils	0.78	0.51	0.80	0.94	0.91	0.94
Male Names	0.37	0.57	0.03	0.93	0.93	0.92
Mammals	0.89	–	–	0.95	0.95	0.94
Metals	0.87	0.81	0.88	0.94	0.98	0.94
Musical Instruments	0.82	0.76	0.76	0.97	0.96	0.96
Nonalcoholic Beverages	0.84	0.72	0.61	0.95	0.95	0.96
Plants	0.64	–	–	0.87	0.94	0.87
Precious Stones	0.77	0.81	0.85	0.96	0.95	0.96
Professions	0.70	0.67	0.52	0.87	0.87	0.88
Reptiles	0.83	–	–	0.97	0.96	0.97
Sciences	0.83	0.66	0.65	0.9	0.92	0.89
Sports	0.72	0.72	0.70	0.93	0.93	0.94
Time Units	0.91	0.95	0.92	0.98	0.97	0.97
Toys	0.70	0.60	0.61	0.89	0.88	0.91
Trees	0.64	0.69	0.71	0.96	0.95	0.97
Types of Music	0.89	0.26	0.79	0.92	0.92	0.94
Vehicles	0.86	0.76	0.68	0.96	0.93	0.95
Vegetables	0.85	0.65	0.62	0.98	0.97	0.98
Weapons	0.71	0.75	0.66	0.92	0.92	0.92
Wild Animals	0.80	0.83	0.76	0.96	0.94	0.94

Notes. NA=North American norms; RN1=HA scores for Moscow-Yekaterinburg data; RN2 =HA scores for Moscow-Irkutsk data; RN3=HA scores for Yekaterinburg-Irkutsk data.

We performed a series of analyses of the HA scores. We analyzed the distribution of the HA scores between categories obtained for L1 and L2. As can be seen from the *Table 1*, the HA for L1 and L2 differ markedly between categories. There are categories with high HA scores (like *Alcoholic Beverages, Colors, and Domestic Animals*). There are also categories with much lower HA scores (like *Female Names, Mammals, and Precious Stones*). These results suggest that there are categories that have very similar structures when produced in a native and in a foreign language, but that there are also categories that have dissimilar structures when produced in a foreign language.

For categories with high L1&L2 HA scores, it can be suggested that either the subject's English language vocabulary is better developed, or that there are smaller cross-cultural differences for these categories. The lower L1&L2 HA scores can be explained by strong cross-cultural differences in these categories. Exploring these ideas in further research will require sophisticated statistical analyses of the shape of the L1&L2 HA scores distribution, which should be bimodal if there are indeed two distinct classes of categories.

Some analyses of these ideas can be also done with the current data. For example, some categories in our list may be highly dependent on culture (like categories of non-living things), while other categories (like categories of living things) are not. The first type should be culture-specific and, as such, items in that category should have lower L1&L2 HA scores. The second should be more cross-culturally stable and should have higher L1&L2 HA scores. We divided all categories into two groups (culture-dependent and culture-independent), but found no differences between mean L1&L2 HA scores between the groups ($p>0.05$).

However, we compared the frequencies of all concepts inside the categories between L1 and L2 separately. This statistically more powerful comparison showed that the number of concepts with significantly different concept frequencies between L1 and L2 was greater for culture-dependent categories than for culture-independent categories ($\chi^2=5.6$, df=1, $p<0.01$), thus supporting the distinction between the two types of categories.

Second, we compared the HA scores for categories generated in L1 and L2 to HA scores for categories generated in L1 (Russian) in several regions of Russia (Moscow, Yekaterinburg, and Irkutsk). These last scores reflect the level of intra-cultural stability of categories in Russian. It should be noted that comparison of category frequency norms within a single culture usually shows relatively high HA scores, indicating the high intra-cultural stability of categories (Marchenko et al., 2018; Marchenko et al. 2016; see the last three columns in *Table 1*). This is true even if the participants belong to different generations (Yoon et al., 2004), or if the results of two tests are separated in time (Marful et al., 2015). In this study, we replicated this result. The HA scores of L1 and L2 frequency distributions were significantly lower than the intra-cultural HA scores between frequency distributions of the three different regions of Russia ($Z=-5.845$, $p<0.001$; $Z=-5.844$, $p<0.001$; $Z=-5.845$, $p<0.001$).

Third, we compared the category frequency distributions obtained in our study for L1 (Russian) and L2 (English) with the normative frequency distributions collected in North America for English (North American norms=NA). For culture-dependent categories, L1&L2 HA scores were greater than the proximity scores between L1 categories and NA, and between L2 categories and NA (χ^2=13.195, p=0.001; L1vsNA: Z=−3.391, p=0.001; L2vsNA: Z=−2.523, p=0.012). For culture-independent categories, the L1&L2 HA scores did not differ from both the L1&NA and L2&NA HA scores (χ^2=0.400, p=0.819; L1vsNA: Z=−0.455, p=0.649; L2vsNA: Z=−0.142, p=0.887). This result clearly supports the notion that there are different subtypes of categories which are more or less universal across cultures. Interestingly, this result also suggests that (for culture-dependent categories) when an individual switches to a foreign language, there is still a strong influence of the native language's conceptual organization on category generation in the foreign language.

On a general note, our results support the idea that when switching to a foreign language, an individual activates conceptual knowledge associated with the use of the foreign language. We frequently observed that when a subject switched to English, he/she began to name concepts which are inherent to the culture of that language (for example, English names in *Male* and *Female Names,* or *mile* and *foot* instead of *kilometer* and *meter*).

However, this idea should be qualified, as suggested, for instance, by our last empirical result. When a person generates items for categories in L2, activation of his conceptual knowledge takes place. In cases where there has been little direct interaction with the objects in the context of L2, the person will probably translate concepts that are familiar to him or her in the context of L1. This may explain how individuals, while to some extent switching to the culture representing a foreign language when they are using it, at the same time may be influenced by the conceptual knowledge of the native language. So, the degree of cross-cultural universality of generated categories, and the experience of the interaction with exemplars from these categories within different linguistic contexts, both affect performance in cross-language category fluency tasks.

Conclusion

This study demonstrated that categorical fluency rates are greater for an individual's native language than for a foreign language. When a person switches to a foreign language, he/she begins to use the words inherent in the culture of that language. The similarity between the frequency distributions of words generated in L1 and L2 is lower than the similarity of such data within one culture. Such differences, connected with the specificity of a person's experience using the foreign language, must be taken into account when assessing the features of semantic categorization. There is evidence that an individual using another language begins to behave as a representative of the culture whose language he uses. Such transformation is echoed in the differences of categorical norms obtained in a cross-linguistic category fluency task in this study.

Although appearing merely theoretical at first glance, these results can also have practical consequences. First, in the process of studying a foreign language, an individual usually acquires culture-specific words, which leads to the establishment of a foreign culture-specific vocabulary. Such data can be used to assess the vocabulary of individuals learning a foreign language, as well as to assess the level of proficiency in that new language. The practice of introducing new vocabulary in semantic categories is a popular approach in second language teaching (Finkbeiner & Nicol, 2003).

Second, our results corroborate the previous findings that the category fluency of bilinguals, even in their native language, can be significantly different from that of monolinguals (Baus et al., 2013). This makes it necessary to develop separate category norms for such individuals, which can be used to diagnose different cognitive impairments, since multicultural contacts and the use of more than one language is a hallmark of the modern world, at least for the large population of Russian-speaking individuals who study and use a foreign language.

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Notes on the "Self-Centered" Factor, Based on Data from Child Language Acquisition

Velina Slavova

New Bulgarian University, Sofia, Bulgaria

Corresponding author. E-mail: vslavova@nbu.bg

Background. This study is based on large samples of language-data collected during the formative period of language acquisition (9–62 months) from free dialogues of English and French children. Analysis of the longitudinal development of children's vocabularies expressed in terms of Parts of Speech showed that their acquisition develops surprisingly differently in these two languages. The hypothesis of the study is that first-language acquisition should respect identical principles, independently of the language acquired.

Objective. To analyze the observed properties of language acquisition data based on a general model of concept formation and information processing.

Design. Two models were applied: (a) Model of information processing based on reasoning concerning information, entropy, energy optimization, and evolution; and (b) Model of native semantic roles, based on the psychological approach of grounded cognition. The common factor in the reasoning applied in these models is that the process of concept formation is based on information generated by the biological system itself.

Results. A joint formal representation is obtained using these two models. The derived mathematical formalism showed remarkable agreement with the sample data. It explains the gradual acquisition of the two languages as one and the same process. The formal description suggests that the acquisition of verbs is accomplished with reference to the concept of Self as Actor, acting in the Environment.

Conclusion. The performed analysis is in support of the hypothesis that there exist inborn mechanisms of concept formation. The investigation of the joint model suggests that the concept of Self plays a central role in the language faculty.

Keywords: language acquisition, corpus analysis, mental representation, concept formation, Self

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Introduction

This study is based on the author's formal analysis of data pertaining to acquisition of two languages, English and French (cf. Slavova, 2017, for full details). The statistical treatment made evident a very high mathematical similarity between the acquisition processes. The data analysis revealed that it is impossible to explain the mathematical "fit" by applying reasoning based solely on language ingredients (parts of speech, syntactic structures, etc.). This prompted a general approach to concept formation, aiming to explain the statistical result by means of models based on a larger scale of factors. The question addressed here concerns the relationship between meaning as a product of mental computations, and language. The reasoning applied relies on the widely accepted psychological model proposed by Barsalou (2003), following which the mental representation of the world replicates the frame of an Actor, acting in the Environment. This led to a generalization of the Parts of Speech (POS), expressing them as belonging to classes of meanings with different cognitive complexity. These meaning-classes can be seen as semantic prototypes of syntactic categories. From this point of view, the study's overall approach can be seen as a statistical investigation related to the "semantic bootstrapping hypothesis" proposed by Pinker (1987).

The notion of the existence of inborn semantics is not new. For example, Wierzbicka (1996) proposed that there exist "semantic primes" which are universal for all languages. Such approaches investigate concrete concepts, proposed to be primary for mentally representing the world. However, the mental capacity to "calculate" the meaning of the concepts has not been investigated in previously proposed models. The principles related to information processing following which the mental representations underlying the language faculty arise and are implemented in language have still not found an explanation. The present work is an attempt to make a step towards clarification of these questions.

Methods

Goal and Tasks of the Research

The goal of the study is to investigate the mechanisms of concept formation that assist children at the initial moment of language acquisition. The study aims at discovering information models of concept formation that can explain the statistical observations of data pertaining to acquisition of two languages. Next in this paper, an analysis is proposed concerning the role of self-referential information with regard to its importance for concept formation.

Research Design and Procedure

The general steps performed to find similarities in the language-acquisition process of the two sampled language-groups of children, briefly reported here, are:

1. Annotated data for the initial period of acquisition is organized into a form treatable for further comparisons.
2. A model is built, based on the psychological model proposed by Barsalou (2003), which discriminates what "type of thing" children were thinking when saying the words.

3. A hierarchical model of conceptualization mechanisms is built. It represents the process of creating information units, which ensures maximal entropy (i.e., delivered information-content) with minimal operational load.

The two models suppose that information is created with an active and constant inclusion of self-referential information. This self-referential mechanism is further explained and analyzed.

Description of the Samples

Data from 42 corpora containing 1,515 free dialogues with children's speech in English and French were extracted from CHILDES (Child Language Data Exchange System, see, e.g., MacWhinney, 2014) and used for statistical analyses (Slavova, 2016). The dialogues in the source were collected, transcribed, and annotated with POS by researchers in language acquisition. The results for two large corpora collections — 125,873 child sentence-utterances for English and 153,824 for French — were treated statistically. The E dialogues (with 62 girls, 66 boys, and 7 children with gender not specified in the nglish data collection contains 620 source); the French collection contains 895 dialogues (with 157 girls and 141 boys). It is important to underline that in the examined samples, children express themselves in free dialogues where they wish to communicate their thoughts, desires, and intents. The majority of the stored utterances are grammatically incorrect sentences, where children structure their expressions as well as they can in order to convey their ideas and wishes. The children are between 9 and 62 months old. They use, with mistakes, the learned language-labels to express the meaning that exists in their mental world. Despite such mistakes, an important assumption in this study is that the collected data are thoroughly relevant for studying the process of concept formation.

All the pronounced utterances in the obtained English and French data collections were treated as follows:

1. For studying the use of POS, the statistical analysis relies on the annotation performed by the authors of the respective corpora.
2. To reflect one main assumption of the model, the utterances were annotated for the present study with an additional feature: "self-centered" speech. The following two cases were considered: (a) the utterance contains the pronouns "I", "me, "mine", "my", or "myself"; (b) the utterance is not well-pronounced; the pronoun is missing, but should be one of those above.

In the first months of speech, children often use verbs without the pronoun "I", as if it were clear that the only possible actor is the speaking child (children also use their own name or, for example, "baby" to refer to themselves). After 36 months, such hidden use of self-centered speech is rarely encountered in the examined data collections. These "hidden Self" utterances were retrieved and manually annotated.

The quantitative analysis of the use of POS was obtained using a measure for the contribution-weight of a given POS within a speech-utterance. The following formula for calculating the Ratio per Utterance (RU) of the given POS within a dialogue was applied:

$$RU(POS_{ij}) = \frac{NPos_{ij}}{N_j} \tag{1}$$

where: POS_i is one of the POS annotated in the corpora, j is the dialogue, N_j is the number of utterances with recognizable POS in the dialogue j, $NPos_{ij}$ is the number of the POS_i in the dialogue j. The Ratios per Utterance show the extent of use of the given POS for expressing the child's thoughts within a communication utterance "averaged" for the dialogue.

Analysis of the Data Samples

The statistical analysis showed that the developmental paths for the use of identical POS in the speech produced by English-acquiring and French-acquiring children are astonishingly different (Slavova, 2017). The average between-languages correlation in the advancing use of identical POS is relatively small — only 0.46 (since POS frequencies on age functions are monotonically rising, the between-language correlations are typically inflated). The question was how to capture the mental representations expressed in the children's words, so as to allow identification of shared principles in constructing a representation of the world.

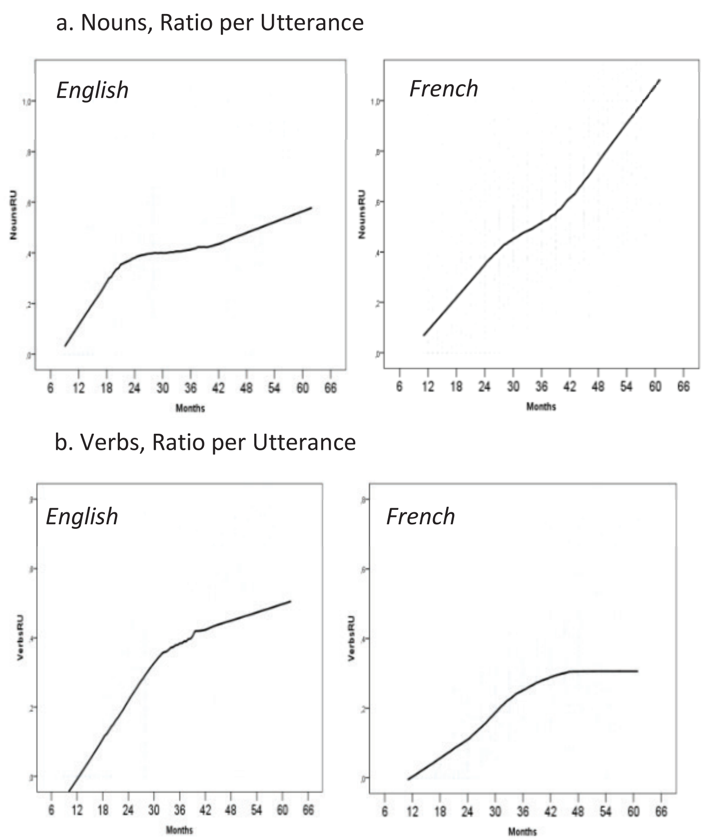

Figure 1. Use of nouns and verbs, age 9 to 62 months

The most basic grammatical categories — nouns and action verbs — have, at least within the Indo-European language family, the same deep semantics. However, as shown in Figure 1, even these basic categories have very different paths of use for expressing the developing ideas of the English- and French-acquiring children. There is no reason to suspect that 1-, 2- and 3-year-old English and French children have very dissimilar ideas to communicate, so the hypothesis is that these ideas are spelled out by means of groups of POS. This prompted the constitution of "classes of meaning" — groups of POS with a similar role from the point of view of the child as an Actor in the Environment.

Application of Mathematical Models

Models of language can be constructed on the basis of particular sets of scientific facts. One main question related to the language faculty is that of *meaning* — a phenomenon for which there are several definitions and approaches. The approach proposed in my previous works (e.g., Slavova, 2018) and followed here assumes that meaning is represented in terms of "information units", which correspond to specific activations of the brain in response to the perceived world. How the brain produces meaning and how it functions in general are questions that still lack complete answers; however, the models proposed here follow reasoning based on results obtained in the brain sciences. Such results suggest that the brain is a closed system with intrinsic activity. It is known that there exist neurons with intrinsic oscillatory capabilities and that "the brain self-generates dynamic oscillatory states which shape the functional events elicited by external sensory stimuli" (Llinás & Paré, 1991). Based on a large set of facts from the domain of the brain sciences, Llinás (2008) concludes that: "subjectivity is what the nervous system is really all about, even from the most primitive levels of evolution". Llinás (2001) furthermore posits that all perceptual and cognitive faculties evolved expressly so as to optimize animals' ability to generate actions required for surviving in their environment.

The modeling approach adopted here reflects this self-generating property of the brain, seen as a closed system with intrinsic activity, as well as the phenomenon of subjectivity, which appears deeply encoded in the functioning of the nervous system.

The Actor in the Environment Model

This is a model of categories of information or "*classes of meaning*" that humans create about the world. The classes of meaning proposed (Slavova, 2017) are the products of general reasoning as to the character of the information that has to be managed by a hypothetical autonomous system displaying complex, goal-oriented behavior as Actor in the Environment. This led to the following classes: *Entities*, *Relationships*, *Circumstances*, *Quality and Attribution*, *Quantity and Precision,* and *Other*. A separate Entity is attributed to Self — the Actor.

In order to statistically test the model's reliability, children's expressions were categorized according to the proposed classes of meaning. The statistical data were used as sources to obtain metadata corresponding to the model. The application of the model made evident that the two language-acquisition processes are very similar (Figure 2). The pattern of acquisition of the meaning-classes displayed a high between-languages class-to-class correlation (Pearson's $r = 0.78$, $p < 0.001$). Examination of the data showed that all the meaning-classes start being used from the outset of speech production, that is, at 10–14 months. This indicates that the semantics of the proposed classes is fundamental (Slavova, 2017).

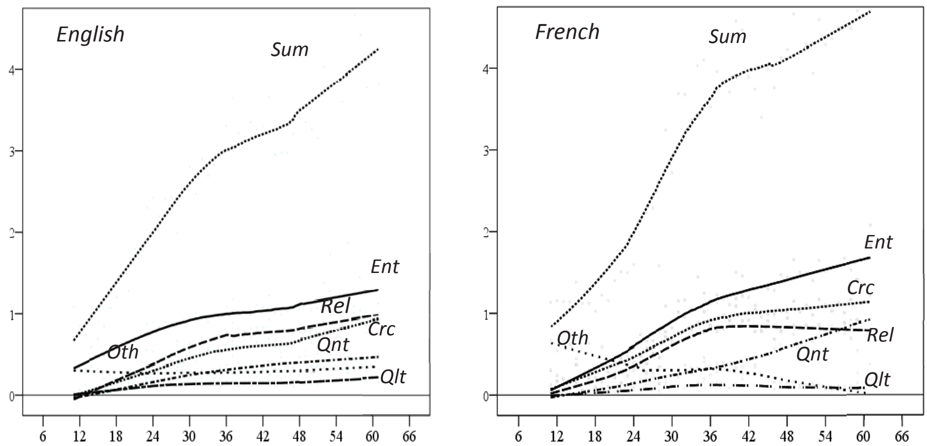

Figure 2. Use of the meaning-classes, age 9 to 62 months (Slavova, 2017).

Note: Ent = Entities, Rel = Relationships, Crc = Circumstances, Qnt = Quantity, Qlt = Quality

The statistical analysis showed that the rates of acquisition of the different meaning-classes are different (Figure 2). For example, Entities are acquired much more intensively in both languages — so, are Entities more easily conceptualized? This suggests that the information processing involved in the conceptualization of the different classes of meaning has different levels of complexity. The further investigation has necessitated the construction of a mathematical model of information processing. That proposed and used here (Slavova, 2018) is based on well-known principles in physics and information theory. The mathematical approach applied aimed at finding an optimal solution when maximizing the entropy (the information) and minimizing the energy cost of the information treatment.

The Maximizing of Entropy Model

One basic assumption in the Maximizing of Entropy information-processing model (previously proposed, see Slavova, 2018) is that information is created by means of a joint treatment of two signals — one coming from the environment, and the other generated within the organism. This led to an information-treatment model in the form of a binary processing tree. The creation of information was presented as a result of a binary operation of "information gathering", called *i-Merge*. Each i-Merge operates on a node of the tree by detecting disparity. Operation i-Merge has two inputs — one exogenous and one endogenous. Both convey encoded information units (this is called an information flow). Each i-Merge produces a novel information unit (novel information flow) based on the dissimilarity between the two incoming information flows.

The bottom-up successive i-Merges form paths that underlie a process of generating more complex levels of information. It has been shown (Slavova, 2018) that such processing obtains maximum classified information with minimal processing cost (energy) when it respects the settings of a theorem demonstrated by Horibe (1982, 1983). Horibe showed that in a binary tree with n terminal nodes weighted with probabilities $p_1 = p_2 = \ldots = p_n$, $\Sigma p_i = 1$, the Shannon entropy is maximized, with minimal average cost, by a Fibonacci tree.

The obtained processing tree is presented in Figure 3. The information processing over the tree is bottom-up. There are two categorical sources of information — exogenous, coming from the environment, and endogenous, providing information intrinsic to the biological system itself, including memory. The terminal nodes represent inputs from multimodal perception (coupled exogenous-endogenous) and memory. The entire information processing relates these sources in a joint information channel.

This formal mathematical expression of the principle "maximal entropy with minimal energy" became possible due to the inclusion of the information flow created by the system. This information flow is created by the processes pertaining to the system's own functioning. As a result, the model describes the gradual assembling of information units over the processing hierarchy as being "Self-referential". This led to naming the obtained formalism a "*Self-centered*" model.

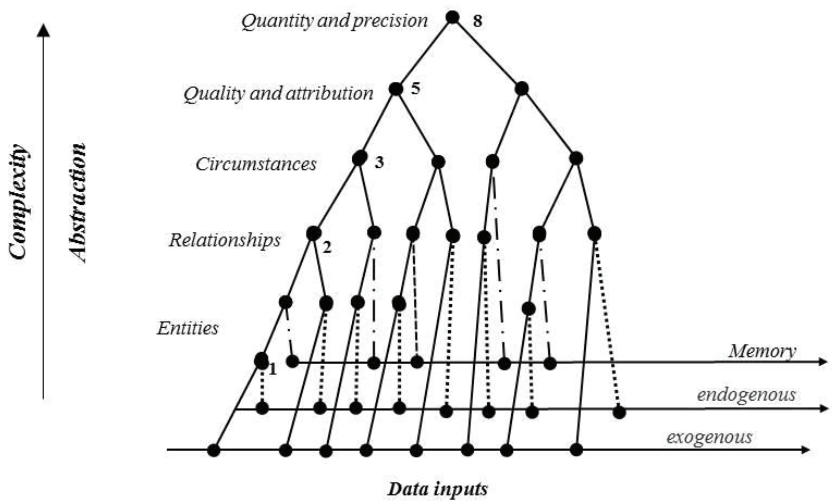

Figure 3. Information treatment model (Slavova, 2018).

Results

Convergence of the Applied Models and the Child-Speech Data

To relate the information-processing model to the dissimilar complexity of the meaning-classes (Figure 2) that became evident after the statistical analysis of the child-speech data, the hierarchical information processing (Figure 3) was expressed in terms of computational complexity. A measure of the processing load was determined as follows: The cost of each level has a value equal to the number of primary information units (i.e., perceived sensory information) entering the corresponding sub-tree through the exogenous input. The meaning-classes inferred from the Actor in the Environment model were placed in the successive levels of the hierarchical processing. As shown in Figure 3, the cognitive processing loads attributed this way are: Entities = 1, Relationships = 2, Circumstances = 3, Quality = 5, and Quantity = 8. This order (Slavova, 2018) signifies the level of abstraction of each meaning-class. Entities are directly based on multimodal perception. Relationships are concepts about the actions and states of Entities, and obtain a concrete meaning when referred to Entities. Circumstances include spatial and temporal characteristics of Entities and/or Relationships. Quality and attribution require extracting of similar features from Entities, Relationships, and Circumstances, and blending them in separate concepts. Quantity and precision need the establishment of concepts that estimate proportions, grouping of Entities, or selecting one Entity from a conceptualized group.

The derived complexity of the classes was used for verification of the model with the statistical observations. The complexity of the concepts (CC) used in the children's speech by the two language groups was calculated as follows:

$$CC = 1.\,Ent + 2.\,Rel + 3.\,Crc + 5.\,Qlt + 8.\,Qnt \qquad (2)$$

where: *Ent*, *Rel*, *Crc*, *Qlt,* and *Qnt* are the statistical results for the Average Ratio per Utterance of the use of classes of meaning ($ARUM_{e,f}$) proposed in the Actor in the Environment model, where ($ARUM_{e,f}$), for the two languages correspondingly — English and French — is calculated with the equation:

$$ARUM_{e,f}(Cl_i) = \frac{\sum_{m=1}^{M_{e,f}} \left(\frac{NCl_{i,j}}{N_j} \right)}{M_{e,f}}$$

where Cl_i is one of the classes of meaning (*Ent, Rel*, *Crc*, *Qlt,* and *Qnt*) used by the children, *j* is the dialogue, N_j is the number of utterances in the dialogue *j, NCl_{ij}* is the number of the words from the class Cl_i in the dialogue *j* , $M_{e,f}$ is the number of dialogues, and the indices *e* and *f* are for the English and the French data collections, respectively. The Ratio per Utterance of a class of meaning NCl_{ij} / N_j shows the extent of use of the given class for expressing the children's thoughts within a communication utterance "averaged" for the dialogue.

The application of this model-derived equation to the statistical observations led to a very high between-languages correlation ($r = 0.933$; $p < 0.01$) for the development of language production. The hypothesis (in statistical terms) that such a between-languages correlation could be obtained by chance was rejected at $p < 0.01$ via Monte-Carlo bootstrapping (Slavova, 2018).

This model offers a hint as to the principle whereby information arises in living matter. The analysis and reasoning provided in Slavova (2018) have proposed that the internal creation of information uses internal "prototypical" signals to create information units about the Actor's environment. This suggestion is additionally supported by a very recent theory in neuroscience, the "Neural Self-Information Theory", postulating that neurons generate synchronized spiking as "Self-Information" codes (Li et al., 2018). The described approaches used for the models are different, but converge, as shown in Figure 3, to a joint representation that explains data from language acquisition of the two languages as one and the same process.

Model of the Process of Conceptualizing Verbs

As seen in Figure 3, the model suggests that concepts can be formed only with active inclusion of an internally generated self-referential information flow. A fundamental question in this representation is what is "given" as a self-referential information flow at birth, such that the brain can start constructing a semantic representation of the world. The main model-based hypothesis which follows is that the verbs are concepts that are strongly related to the concepts of Self. The reasons for this hypothesis are briefly explained below. The mental representations that correspond to the recent findings discussed below are referred to as the concepts of "*Self*" and "*Self-similar*".

Analysis of Findings from Brain Sciences

A previous analysis (Slavova & Soschen, 2015a) led to the conclusion that genetically determined information processing realizes the concept of Self by means of proprioception, interoception, processing by the Mirror Neuron System (MNS) (e.g., Rizzolatti & Craighero, 2004) and by the Default Mode Network (DMN) (e.g., *Horn,* Ostwald, Reisert, & Blankenburg, *2013).* Numerous brain studies have been conducted toward identifying the processes by which the concept of Self is established. For example, Davey and colleagues (2016) suggest that a composite "brain-Self" system is responsible for engendering conscious self-awareness which provides the sense of oneself as a subjective Agent. The effort to understand brain functioning related to the concept of Self has led to "Countless functional neuroimaging studies..." (Tsakiris, 2017), which have reported various brain structures and processes related to the concept of Self. The result of these efforts has not still provided a definitive explanation for the phenomenon "Self", but they all indicate the existence of brain mechanisms underlying a precise mental representation associated with what we have termed the concept of Self.

Other brain-imaging results (e.g., Connolly & Haxby, 2012; Molnar-Szakacs & Uddin, 2013a,b) show that the brain reacts in a specific way to perceptual features that are "Self-like" (including of animals, especially mammals). Recent fields in brain research such as the "social brain sciences" (Adolphs, 2003) have revealed neurobiological links between the Self, emotion, and society. Other results report an overlap between the DMN and brain areas mediating social cognition (e.g., Mars et al., 2012). Such efforts led to another discovery: that the brain mechanisms associated with the concept of Self are related to a specific conceptualization ability — the understanding of the Self as a part of a society or, in other words, the availability of a categorical concept corresponding to the *Self-similar*. In a sense, these research areas may be reduced to the question, *"How do humans recognize conspecifics?"* Papeo and colleagues (2017) interpreted this question as asking "*what it means to recognize humans*" and found, based on brain imaging, that this ability involves brain patterns treating perceptual characteristics of conspecifics and the retrieval of more abstract information that determines category membership (human or nonhuman). The brain mechanisms that correspond to such recent findings suggest the existence of a biological basis underlying the concept of "*Self-similar*".

Modeling the Conceptualization of Verbs

The model's processing tree (Figure 3) suggests that the creation of an information unit corresponding to an Entity can be accomplished solely by the neural substrates of multimodal perception. This is not the case for the Relationships (Verbs). Verbs, as the model suggests, necessitate additional memory input. For instance, analysis of adults' fMRI results led Di Cesare and colleagues (2017) to conclude that an action verb "prepares us to interact with an object even though no object name is presented in our linguistic stimuli (the object is very likely inferred by the participants)". This suggests that conceptualization of action verbs uses semantic memory.

The assembly of larger volumes of mentally operable information depends on the capacity to manage the argument structure of a sentence. It was shown on the basis of data from the English collection (Slavova & Soschen, 2015b) that the assigning of thematic roles in children's sentences occurs gradually with age, by means of the successive inclusion of sentence arguments as follows: 1. S-V; 2. V-O; 3. S-V-O; 4. S-V-O-O. The important observation was that the first uses of these argument frames start, for each of the enumerated structures, by composing sentences in which the Self is the Subject. The observed intensive use of expressions with the Self as Actor suggests that verbs are assisted by "mirroring" of perceived actions of the Self-similar.

The term "mirroring", following its use in the specialized studies of MNS (e.g., Mihov et al., 2013), denotes the automatic process initiated by the MNS, consisting of various types of activation of the person's own body and emotional state in correspondence with that observed in other humans. Concerning the acquisition of verbs, the hypothesis suggested by the information-processing model is that when observing other people's actions, *mirroring* creates a mental activation which corresponds to one's own action, accorded to the concept of Self. This assists the creation of a concept "ready to use" in speech, where the Self is the Actor in the sentence (in accordance with the Actor in the Environment model). This supposes that the mirroring assists children in the creation of concepts for verbs and that the process is based on the concepts of Self and the "mirrored" Self-similar.

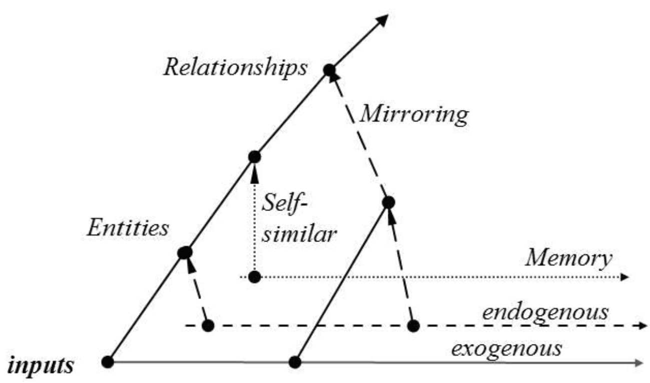

Figure 4. Mirroring of the Self-similar to conceptualize verbs.

In compliance with all the enumerated data, the Maximizing of Entropy model is further developed in the context of mirroring (Figure 4). Relationships (verbs) are conceptualized on the basis of three types of inputs: the coupled exogenous-endogenous inputs, creating a perceptual unit, and an input conveying memorized Entities. This scheme proposes that the inputs facilitating the conceptualization of verbs necessitate the perception of actions of the Self-similar in order to match them to the Actor's own actions and intents. At the time of birth, an infant's semantic memory is (at least) very meagre, as the newborn has still not experienced the outside world. Following the scheme in Figure 4, the information processing required for conceptualizing relationships cannot ensue without a representation of the Self-similar. The model suggests that the awareness of the Self-similar is genetically underpinned.

This model's prediction is supported by several studies of newborns' reactions to human faces or voices, suggesting that such awareness exists at birth. As an example, Streri and colleagues (2013) demonstrated that just hours after birth, human infants are capable of imitating human facial movements. These authors propose that there exists an innate predisposition to social interactions in newborns. Although it is difficult to investigate the neurobiological basis of such phenomena, novel and adapted fMRI methods make it possible to suggest an answer to the question: Does the concept of Self-similar reflect innate predispositions? A recent fMRI study by Deen and colleagues (2017) demonstrated that, while the anatomical maturation of the human cortex is slow and asynchronous, by 4–6 months, human infants' visual cortex already has a spatial organization mimicking that of adults, mediating category-sensitive responses to human faces and to environmental scenes.

Discussion

Note on Piaget's "Egocentric Stage"

The Self-centered characteristic of the model presented here is not related to the "egocentric stage" described by Piaget (e.g., Piaget, 2015). Piaget notes that the incidence of egocentric speech slowly dies out between 2 and 7 years as that of "social speech" increases, where the intent of social speech is to communicate with the social environment.

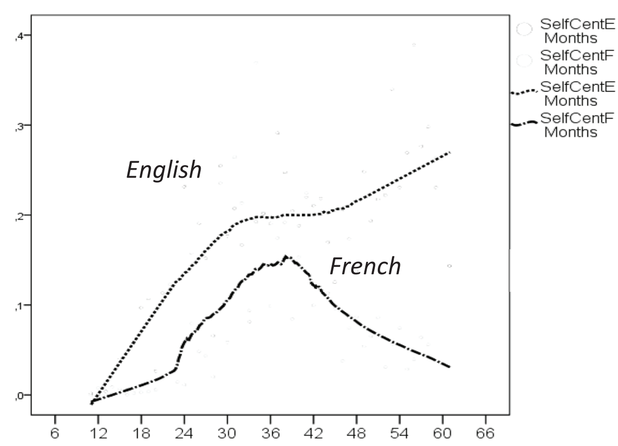

Figure 5. Self-referencing, as measured in speech

According to the present study's reasoning, children try to make their communication as successful as possible from the very outset. The fact that children start expressing, for example, Entities with the words used in the language environment represents already a sign of their communicative intent. As mentioned earlier, in order to follow the progress in the structure of sentence arguments, an additional data annotation was performed to evaluate the child's use of explicit or hidden references to himself or herself.

This provides one more Ratio per Utterance, the Self-Referencing Ratio, showing the participation of pronouns and names that designate the speaking child. The development of this Ratio is shown in Figure 5. The two language groups show a different developmental path in the use of self-referenced speech. After 36 months, the French group utters fewer and fewer self-referenced expressions. The English group does not show a decrease of this use, but rather a period of lack of increase.

If one assumes that the use of self-referencing is a sign of egocentric behavior and that the particularities of the two languages do not influence the use of self-referencing (which does not seem true), the English group does not correspond to the observation of Piaget. However, as seen from the plot presented in Figure 5, for the period 11–36 months, the two language groups show a net tendency to advance in speech production when referring to themselves (for this period, the between-languages Pearson's r is 0.586, $p < 0.001$. The self-referencing stage, from the point of view of the model here, is related to the initial frame for representing the world, in which the Self is the Actor. The hypothesis that can be considered for the later period is that after 36 months, children start being strongly influenced by everyday vernacular usages of language typical among older speakers.

Some Comparisons with Findings from Child Language-Acquisition Studies

Studies of children's language acquisition do not concentrate explicitly on the parameters that are involved in the model presented here; however, examination of the reported studies in this field can identify several findings that are supportive of the model.

The main hypothesis concerning verb acquisition implied by the model pertains to children's awareness of the Self and the Self-similar. More precisely, the hypothesis is: When the child can perceive an action performed by a Self-similar, perception and mirroring "automatically" map it onto the child's inborn information flows, assisting the creation of the verb concept. To produce sentences with the Self as actor necessitates one single mental step after the automatic mirroring: the use of the verb with its conventional public label. Such a scheme leads to the supposition that actions that are not observed as performed by the Self-similar should be more difficult to conceptualize. When the child has to give a name to a self-formulated action that has never been observed as performed by a Self-similar, the conceptualization will lack the input necessary to directly prompt the mirroring. In this case, two mental steps will be needed for creating the verb concept: step 1 — (mental) projecting of one's own action onto a Self-similar Entity; step 2 — mirroring the imagined action of the Self-similar in order to prompt the automatic creation of the verb concept.

Studies in verb acquisition are supportive of this hypothesis. Childers and Tomasello (2006) examined children's comprehension and production of new verbs using several conditions, including training with either the Self-agent or a Self-similar puppet agent. The result showed that "when children initially heard a new verb that referred to their own actions, they were better at responding to questions that referred to their own actions than questions that referred to another agent's actions.

This was not true of the verbs in which children saw a puppet agent". (Childers & Tomasello, 2006). Other studies of language acquisition resulted in further findings related to the Self-similar hypothesis. For example, Mandler (2006) showed that 14-month-old infants typically refuse to imitate actions that are contextually inappropriate, such as putting a toy vehicle to bed or giving it a drink.

Following the present model, it can be supposed that verbs that denote actions of a Self-similar are more easily conceptualized and will outnumber the other verbs in children's speech. Indeed, the results of Buresh and colleagues (2006) showed that verbs describing events that involve actions by other people are prevalent in children's vocabularies. These authors suggest that "understanding the actions of others is critical for discerning their communicative intentions, and thus provides a foundation for all aspects of language learning, not just verb learning".

Evolution and the Concept of Self

A further question is whether the information processing that assists the mental representation of the world from the standpoint of a goal-oriented Actor who has an idea about the Self is uniquely human. It is not currently clear how exactly the awareness of Self emerged in the course of evolution, but it is known that some non-human primates (namely the great apes) successfully pass the standard "mirror self-recognition test" (e.g., Anderson & Gallup, 2015; Gallup, 1970; Robert, 1986; Westergaard & Hyatt, 1994) as well as some non-mammalian species (e.g., Delfour & Marten, 2001). This is strong evidence of self-recognition in animals and indicates the possibility of self-awareness ("sense of self"), but not a definitive proof. Concerning the neurobiological aspects of the phenomena related to the awareness of the Self and of the Self-similar, it should be noted that the MNS, originally discovered in macaques, has been recognized in several other species (see, e.g., Rizzolatti & Craighero, 2004). As regards the DMN, crucial for mediating introspection, a number of studies (e.g., Vincent et al., 2007) discovered that it exists in nonhuman primates. Mars and colleagues (2012) propose that many facts revealed by studies of DMN in nonhuman primates show an evolutionary aspect of DMN's functional organization, which in humans displays a degree of overlap with areas that mediate social cognition.

There are reasons to believe that the mental mechanisms discussed here arose in pre-human evolutionary development and exist to some extent in nonhuman primates. Accordingly, there are no reasons for nonhuman primates not to develop such an elaborated language as that of humans. But they did not. To find the precise reasons necessitates serious efforts in several domains.

So, for the moment it is not clear whether only humans have a concept of Self. However, an anthropological model of evolution recently proposed by Messori (2016), exploring evidence and results from several anthropological investigations, advises that the conceptualization of the Self as a Subject within a subject–environment relationship (Subject–Object, as presented there) triggered the language faculty.

Conclusion

The examined speech data and the hypothesis prompting the various forms of analyses undertaken by me here and elsewhere, led to the inclusion of a Self-referential parameter in the proposed model. The application of this resulting Self-centered model showed remarkable convergence with the data and explains child language acquisition of the two languages as a common process. The model proposes that verbs are conceptualized by means of hierarchical information processing reliant upon the concepts of Self and Self-similar. The model advises that the establishment of these concepts is assisted by phylogenetically transferred information.

Limitations

This model and the derived conclusions are based on already-annotated data collected from two language samples. The annotated child dialogues used are available in the CHILDES data repository. The generalization of the conclusions for more languages and for human language in general can be pursued by way of including samples from other languages. For the moment, there are no other language samples in the CHILDES repository that are in themselves sufficient in size and contain the necessary annotation to perform a similar statistically reliable analysis. With the inclusion of more language samples, the statistical picture might possibly converge on the model proposed here or lead to other assumptions, models, and reasoning.

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Possible Cognitive Mechanisms for Identifying Visually-presented Sound-Symbolic Words

Liubov O. Tkacheva, Yulia G. Sedelkina*, Andrey D. Nasledov

St. Petersburg State University, St. Petersburg, Russia

* Corresponding author. E-mail: yulsedspb@gmail.com

Background. Sound symbolism (SS) refers to the direct association between the sound and the meaning of a word. The results of cross-linguistic research prove that SS is universal for different languages and cultures. Thirty percent of all natural languages consist of SS words. But despite the large number of psychosemantic studies which have been conducted, the cognitive mechanisms of the perception of SS words still remain unclear.

Objective. The aim of this study was to determine how Russian-speaking subjects perceive visually presented English and Russian words, as measured by the Lexical decision method.

Design. The study sample consisted of 148 subjects of ages ranging from 13 to 78. The study was conducted in two stages. During the first stage, the perception of visually-presented English SS words by Russian learners of English, with three different levels of language proficiency, was studied. During the second stage, the perception of visually-presented Russian SS words by Russian native speakers from three different age groups was studied.

The stimuli material was selected according to the following criteria: 1) ach word was monosyllabic; 2) Each SS word corresponded to a single arbitrary (non-SS) word of the same pronunciation type; and 3) Each word corresponded to a non-word, formed from it by replacing letters according to the phonotactic rules of English and Russian. At each stage of the study, each subject was given 80 stimuli consisting of 20 SS words, 20 non-SS words, and 40 non-words. An analysis of contingency tables (Chi-square test), comparison of averages (Student's t-test), and analyses of variances (ANOVA) were applied to the data.

Results. The visually-presented SS words were identified more slowly and with more errors than the non-SS words, regardless of the language (Russian or English), the subjects' age, and their English language proficiency.

Conclusions. The observed delay effect in the cognitive processing of visually-presented SS words is due to the cognitive complexity of the task, which leads to the activation of cross-modal interaction system, besides, interfering systems of information processing are assumed to exist.

***Keywords**:*
phonosemantics, psychosemantics, sound-iconicity, sound symbolism (SS), lexical decision task

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Introduction

Despite the abstract nature of natural languages, 30% of the words in all of them retain an explicit or implicit link between the signified object and the signifying word (Armoskaite, 2017). Such words, which feature close proximity between their acoustic form and their meaning, are called sound-symbolic (SS). Amongst them, onomatopes and ideophones can be distinguished, depending on whether they signify acoustic or non-acoustic sensations (Voronin, 2006). Thus, SS words evoke ideas of sensual images which can be represented in a wide range of perceptions within all sensory modalities–from sound to movement or texture, from appearance to internal feeling (Dingemanse, 2018).

For a long time most of the research on SS has focused on its phonological, morpho-syntactic, and symbolic aspects (Dingemanse, 2012; Sidhu, 2017), as well as its universal character for all natural languages (Kazuko, 2010; Svantesson, 2017). Lesser works studied the meaning and practical use of SS. Only in the 2000s did the rich sensory meaning of SS words and cross-modal interaction in the process of their decoding begin to be studied (Ameka, 2001). It has been found that, in addition to the direct link with the auditory system of perception, SS extends to other sensory modalities, such as visual, motor, and tactile systems; they sometimes may include internal visceral sensitivity and trigger psychological conditions (Akita, 2009). Moreover, this hierarchy of the sensory impact of SS can be characterized by a multifaceted semantic map, with several possible trajectories of semantic expansion and grooves (Van der Auwera, 2006).

Neurolinguistic studies have set a new milestone, marked by the search for physiological correlates of the cognitive processes involved in decoding SS. In the early 2000s, data was obtained on the high plasticity of the sensory areas of the cerebral cortex, and the propensity for various sensory modalities to interact at the cortical level (Shimojo & Shams, 2001; Ramachandran & Edward, 2001). The most pronounced manifestation of such cross-modal interaction can be found in the studies of how young children perceive SS. It has been shown that, due to the close connections between the sensory areas of the brain, various sensory modalities for speech sounds are spontaneously activated in infants (Walker, 2010). Cross-modal interaction facilitates the understanding of words, allowing the child to concentrate on the referents built into the complex scene (Imai, Kita, 2014). It has been suggested that this early capability for cross-modal interaction may later turn into a more abstract system of symbols (Cytowic & Eagleman, 2009).

Furthermore, it is recognized that SS plays a significant role in teaching languages (Imai, 2008; Laing, 2014; Sedelkina, 2016) and in natural spontaneous communication (Perniss & Vigliocco, 2014; Clark, 2016). Experiments with MRI proved that mirror (mimic) neurons are responsible for receiving onomatopoeia (Osaka, 2006), and that they are also activated in the auditory perception of the sounds easily associated with the recognition task (Rizzolatti & Craighero, 2005). In addition, it has been confirmed that the multisensory interaction in the auditory perception of SS words, is associated with the emotion of laughter (Osaka, 2003).

Taking into account the lack of a clear description of the cognitive mechanisms involved in the processing of visually presented SS words, we decided to compare the speed and accuracy of identification of visually presented SS words, in contrast to non-SS words.

Method

Materials

To collect the data, the "Lexical decision" method was used (Ratcliff, Gomez, & McKoon, 2004) as part of the software complex for longitudinal research (Miroshnikov, 2001). The research was carried out in two stages. During the first, the perception of visually presented English SS words by Russian learners of English with three different levels of language proficiency, was studied. During the second, the perception of visually presented Russian SS words by Russian native speakers from three different age groups, was studied.

Table 1

The stimuli of the first stage

SS words	Arbitrary words	Non-words	
peak	deep	heep	feep
clap	luck	clatt	claff
knock	map	moff	nak
click	pink	stim	pimk
crash	trash	prash	grash
wow	hour	bout	vout
pump	stamp	tunk	pank
bat	cat	pab	cag
tap	top	dod	taf
wind	band	wint	bant
kick	sick	kif	tith
bell	bill	gell	pell
flow	low	fow	lau
glance	chance	lunce	hunce
fly	life	thly	gly
scream	cream	rean	reang
slide	side	lide	shide
slip	pill	silp	siple
snake	save	smake	snate
jump	just	junt	chunt

In the first stage, stimuli material was selected according to the following criteria:

1) All semantic stimuli were monosyllabic English words from the PET vocabulary list (PET Vocabulary List, 2011), representing a B1 level of language proficiency according to the Common European Framework of References for Languages: Learning, Teaching, Assessment (CEFR). This was the level of the majority of the subjects;
2) Each SS word corresponded to a single non-SS word similar in quality and quantity of vowels and consonants; and
3) Each word corresponded to a non-word formed from it by replacing letters according to the phonotactic rules of English, so that it was similar in composition and quality of vowels and consonants.

The SS stimuli consisted of 11 onomatopes and 9 ideophones. Onomatopes were collected from the lexical lists presented in S.V. Voronin's thesis (Voronin, 1969). Ideophones were collected from the phonosemantic dictionary of M. Mag-

Table 2

The stimuli of the second stage

SS words	Arbitrary words	Non-words	
plyukh (splash)	slukh (hearing)	flyukh	khlus
bukh (bounce)	buk (beech)	buj	bun
chmok (peck)	srok (term)	kmok	ksor
shcholk (click)	sholk (silk)	shchokl	shlyok
khlop (clap)	klop (bug)	khlok	klap
gav (woof)	rov (ditch)	vag	rav
pisk (squeak)	risk (risk)	sipk	skipr
bakh (wham)	bar (bar)	khab	rap
skrip (creak)	krest (cross)	skirb	sterk
plesk (splash)	press (press)	pleks	spers
khlyup (squelch)	klub (club)	khluk	bluk
tresk (crack)	trest (group)	tersk	stret
khrup (crunch)	trup (corpse)	prukh	rupt
vizg (scream)	disk (disk)	zvig	ksid
lyazg (clank)	glaz (eye)	zyagl	zagl
khrip (groan)	khrom (chrome)	prikh	mokhr
chirk (strike)	tsirk (circus)	krich	krits
svist (whistle)	tvist (twist)	stisv	svitt
stuk (knock)	kust (bush)	tusk	skut
pshik (puff)	shpik (pork fat)	piksh	shipk

nus (Magnus, 2017). The meaning of the sound combinations with a symbolic sense was checked according to the tables of data from statistical research on SS (Drellishak, 2006). The stimuli used in the first stage of the research are presented in *Table 1*.

In the second stage, the stimuli material was selected according to similar criteria:

1) All words were monosyllabic, collected by the method of continuous sampling from etymological (Fasmer, 1986) and phonosemantic dictionaries (Shlyachova, 2004);
2) Each SS word corresponded to a single non-SS word of the same acoustic type, e.g. bukh (SS word, meaning bounce) to buk (arbitrary, non-SS word, meaning beech); and
3) each word corresponded to a non-word, formed from it by replacing letters according to the phonotactic rules of Russian, so that it is similar in quality and quantity of vowels and consonants, e.g. slukh (a word meaning hearing) to flyukh (non-word).

The SS stimuli consisted of 20 onomatopoetic words which presented all types of phonosemantic sounds: instant (bukh, bakh, stuk, khlop, khlyup), continuant (vizg, gav, pisk, svist, chmok, pshik), frequentative (skrip, tresk, khrip, khrup, chirk), and integrated sounds (lyazg, plesk, plyukh, shcholk) that combine the characteristics of instant, continuant, and frequentative sounds. The transliterated Russian stimuli used in the second stage of the research, along with their English equivalents in brackets, are presented in *Table 2*.

Procedure

The study was carried out according to the classical "Lexical decision" method (Meyer & Schvaneveldt, 1971; Ratcliff, Gomez, & McKoon, 2004) during both stages of the research. A subject received instructions (first orally, and then visually on the screen) explaining the task sequence and telling him/her to make a decision as quickly as possible. Then, 20 SS words, 20 non-SS words, and 40 non-words were presented on the screen in random order one by one (see *Tables 1* and *2*). The subject's task was to identify the presented stimulus as a word or non-word by pressing the button which corresponded to the type of the stimulus. Identification time was restricted to no more than 1000 ms. We collected data on the time required for identification, the number of errors, and the number of delays. The experimental session was preceded by a training one, where 10 words and 10 non-words were presented in random order.

The sample

In total, 148 persons were surveyed. The first stage of the study involved 90 participants, among them 25 male and 65 female, aged 17 to 20 years, who were divided into four groups according to the level of their English language proficiency: 1) 0–A1: 9 people; 2) A2–B1: 15 people; 3) B1–B2: 54 people; and 4) B2+: 12 people. All participants were Russian-speaking first-year B.A. students studying at the faculty of Asian and African Studies, the faculty of Philology, and the faculty of Psychology of St. Petersburg State University who had studied English as a foreign language.

The second stage of the study involved 58 Russian-speaking subjects, divided into three groups according to their age: 1) 15 years old and younger: 4 people; 2) 15-50 years old: 31 people; and 3) 51 year old and older: 23 people. The entire sample included 23 males and 35 females.

Statistical data analysis

In total, 5902 target stimuli were presented. The distributions of correct answers, errors, and delays for SS and non-SS words were compared using the chi-square test. To compare the reaction times for word recognition, the average reaction time for SS and non-SS words was calculated for each subject; hereafter the sequence of stimulus was presented as repeated measures. The comparison was made using the Student's t-test for dependent samples. To check the influence of the level of language proficiency/age on the time taken to recognize the words, a 2-factor analysis of variance with repeated measures ANOVA 2x4 (type of stimuli) and the dependent variable "time" was carried out (Nasledov, 2013). All statistical analysis was performed using IBM SPSS software version 24.

Results

The distributions of delays, correct answers, and mistakes for SS and non-SS English words are presented in *Table 3.*

Table 3

Contingency table of the "Type of stimuli" x "Accuracy" for English words

Words		Accuracy			
		delay	**correct**	**mistake**	**total**
SS	Amount	40	1496	264	1800
	%	2.2%	83.1%	14.7%	100.0%
Non-SS	Amount	34	1595	171	1800
	%	1.9%	88.6%	9.5%	100.0%
Total	Amount	74	3091	435	3600
	%	2.1%	85.8%	12.2%	100.0%

The differences are statistically significant (chi-square=22.606; df=2; $p < 0.001$). The number of correct answers is statistically significantly lower for SS words (83.1%) than for non-SS (88.6%), due to the increase in the number of delays and mistakes.

The times taken for word recognition were compared using the Student's t-tests for dependent samples. The results are shown in *Table 4*. Differences were found at a high level of statistical significance ($t=4.542$; $df=89$; $p<0.0001$; $R2 =0.188$): the average time for SS words recognition is more than that for recognizing non-SS words. The difference in the type of stimulus (SS words /non-SS words) explains 18.8% of the differences in time recognition.

Table 4

Descriptive statistics of reaction time for English words

Words	Mean (MS)	N	Standard deviation	Error of mean
SS words	642.4328	90	72.29333	7.62039
non-SS words	625.4398	90	68.87652	7.26022

According to the results of a 2-factor analysis of variance with repeated measures ANOVA 2x4 (type of stimuli) and the dependent variable "time", the effect of the interaction of factors was statistically insignificant (F (3; 86)= 2.017; p<0.118). Thus, the difference in the time required for recognition of SS and non-SS words is manifest regardless of the level of a subject's language proficiency.

The average values of the word recognition time, depending on the level of language proficiency and the type of stimulus (SS word /non-SS word), are shown in *Figure 1*.

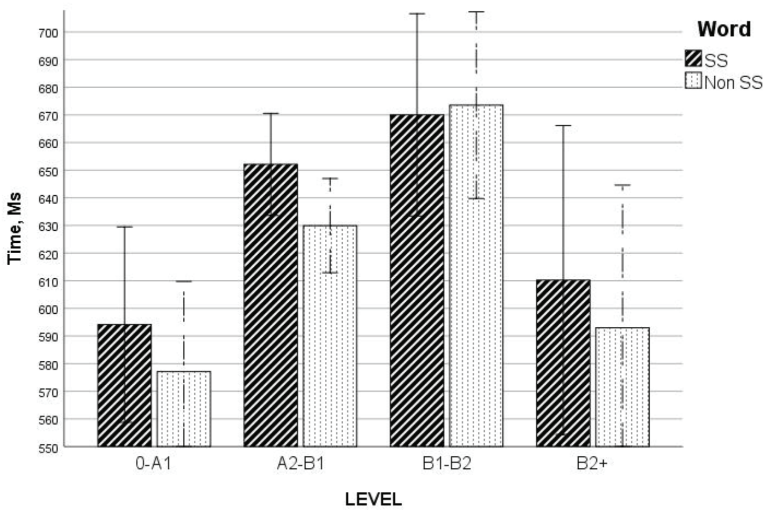

Figure 1. Average values of the recognition time for English words.

In *Table 5* the distributions of delays, correct answers, and mistakes for SS and non-SS Russian words are presented.

The differences are statistically significant (chi-square = 25.253; df = 2; p < 0.0001; phi = 0.105). The number of correct answers is statistically significantly lower for SS words (70.4%) than for non-SS words (79.5%). The effect was tested for each of the three age groups. For the group "up to 15 years," the effect was statistically unreliable, likely due to the small number of the sample (chi-square= 0.144; df=2; p<0.931). However, for the other two groups, the effect is statistically significant. For the sample "from 15 to 50 years" the proportion of correct answers for SS words was 73.6%, and for non-SS words, it was 85.5% (chi-square=30.062; df=2; p< 0.0001). For the sample "over 50 years," for SS words it was 70.4%, and for non–SS, 79.5% (chi-square=6.851; df=2; p<0.033).

Table 5

Contingency table of the "Type of stimuli" x "Accuracy" for Russian words

Word		**Accuracy**			**Total**
		delay	**correct**	**mistake**	
SS	Amount	139	831	210	1180
	%	11.8%	70.4%	17.8%	100.0%
non-SS	Amount	101	938	141	1180
	%	8.6%	79.5%	12.0%	100.0%
Total	Amount	240	1769	351	2360
	%	10.2%	74.8%	15.0%	100.0%

Table 6

Descriptive statistics of reaction times for Russian words

Words	**Mean (MS)**	**N**	**Standard deviation**	**Error of mean**
SS word	743.73	58	63.154	8.292
non-SS word	713.22	58	65.876	8.650

The time for word recognition was compared using the Student's t-test for dependent samples; the results are shown in *Table 6*. Differences were found at a high level of statistical significance (t=5.460; df=57; p<0.0001; R^2=0.343): the average time for SS words recognition is more than that for non-SS words. The difference in the type of stimulus (SS words /non-SS words) explains 34.3% of the difference in time recognition.

To check the influence of age on the time of word recognition, a 2-factor analysis of variance with repeated measures ANOVA 2x3 (type of stimuli) was undertaken, with the dependent variable "time" (ms).

Statistically significant effects of the factor "type of stimuli" (F (1; 55)=17.883; p<.0001) and the factor "age" (F (2; 55)=5.978; p<0.004) were found. The effect of the interaction of factors was statistically insignificant (F (2; 55)=0.953; p<0.392). Thus, the difference in time recognition of SS and non-SS words is manifested regardless of age. The average values of the word recognition time depending on the age group and the type of stimulus (SS words /non-SS words) are shown in *Figure 2*.

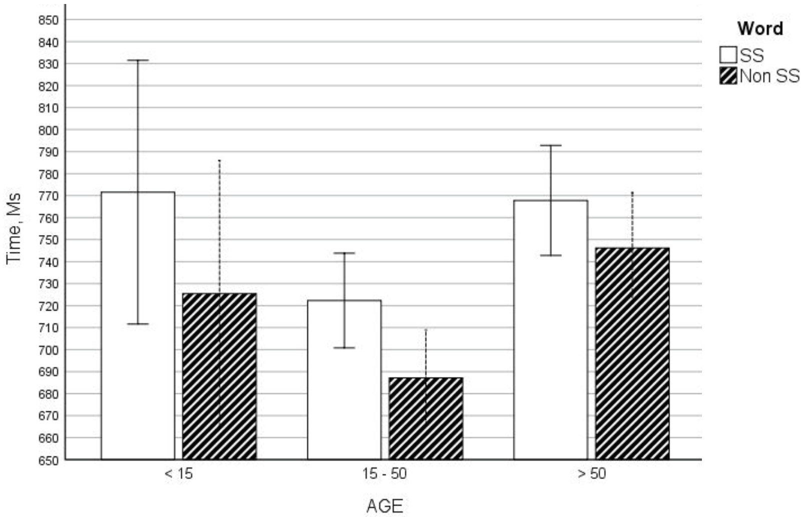

Figure 2. Average values of the recognition time for Russian words.

Discussion

The results show that Russian native speakers recognize both Russian and English SS words more slowly and less correctly than non-SS words when they are presented visually. Furthermore, the magnitude of this effect for Russian SS words (R^2=0.343) is higher than for English ones (R^2=0.188). The result is also interesting because, in total, 40 pairs of stimuli were used in the experiment, while in the majority of studies of SS, no more than eight pairs of stimuli were used (Westbury, 2018).

It would appear that the observed delay in the identification of words is caused by the cognitive complexity of the task, since, in addition to the cross-modal interaction system, two interfering systems of information processing are supposed to be activated. One is the system of decoding semantic information automated in ontogeny, associated with the left-brain contour of functional dominance with dominant right-handedness, and other is the figural system of decoding information that requires the activation of right hemisphere resources.

In the EEG experiment on perception of words and non-words, consistent coherence in the beta range in the left hemisphere was recorded when the subjects perceived the words (von Stein, 1999). Similarly, in EEG research on understanding visually presented texts with the increasing completeness of information, high-frequency activity with the predominant involvement of the left hemisphere in the phase of idea generation was recorded as well (Tkacheva, 2015).

What is also significant is that the delay in recognizing SS words remained regardless of age. But it is also necessary to note that the youngest age group in our study corresponded to the age period of 13-15 years (7^{th} to 9^{th} grades), an age when the system of decoding semantic information has long ago been automated.

Ideas in support of the cross-modal activation theory underlying the process of identification of SS words, have been repeatedly voiced (Ramachandran, 2001).

According to this theory, the search for correspondence between the sound and form of the word can be explained by the presence of sensory connections between the auditory and visual zones of the cortex (Kovic, 2010). EEG experiments on the perception of SS has proved that infants of 11 and 14 months-old process SS information faster than non-SS (Asano, 2015; Miyazaki, 2013). It has also been shown that synesthesia, arising in the process of perceiving SS words and associated with activation of cross-modal integration, contributes to better intuitive understanding of information (Revill, 2014; Bankieris, 2015).

At the same time, in experiments with adults using the method of Event Related Potential (ERP), a delay in cognitive processing of SS information was detected (Lockwood, 2016), as well as a late negative component in the composition of the ERP as an indicator of audio-visual integration (Molholm, 2002).

It is very likely that in the initial stages of ontogeny, SS information is an integral part of speech development. The analysis of a single case cannot directly confirm this assumption; however, in a longitudinal study, it was found that SS was the basis for a bootstrapping mechanism of an infant's speech, both at the lexical and phonological levels (Laing, 2014). In many studies SS is regarded as a stage of the early evolution of language as a linguistic system (Pleyer, 2017; Blasi, 2016). Therefore the analogy between ontogenesis and phylogenesis suggests we should see SS as an indispensable early stage in the formation of the speech system both at the individual and global levels.

The idea of a bi-directional, competing link, semantic and phonological, interfering with the processing of SS words, has already been expressed (Pexman, 2012), but has not been proved experimentally. It is interesting that, when the SS word is perceived by hearing, it is identified more accurately (Revill, 2014), but when it is presented visually, the probability of error is significantly increased. It turns out that the task of auditory identification of SS is much easier than the task of its visual identification. Apparently, with years of continuous training of the decoding system of semantic information using verbal-logical codes and left-hemisphere strategies (under dominant right-handedness), the latter becomes a priority and is activated at each meeting with semantic information. In this case, if the word contains not only a semantic but also a figurative message, the resources of one semantic system are not enough to decode the information properly. Thus, it is necessary to involve additional processing circuits, that can decipher a figurative sensory message which provokes cross-modal interaction

Conclusion

Our data show that, in comparison with non-SS words, visual perception of SS words of both native and foreign language, causes a delay in cognitive processing in adult subjects. This is probably because SS words carry information in two dimensions at the same time: semantic and sensual. For this reason, visual cognitive processing of such a stimulus is more complex and slower, and involves activation of at least two processing loops.

To further this research, we are planning to conduct a psychophysiological experiment with the help of EEG and ERP, registering the bioelectric activity of the brain when it is in the process of decoding SS words, presented both visually and audibly. We hope to get information about the reorganization of the brain's systemic activity in processing SS words. In addition to contributing to the solution of the psychophysiological problem at the methodological level, this will allow us to approach an understanding of neurocognitive mechanisms of perception of SS.

Limitations

This study would have been more complete if it had been possible to collect information about the cognitive processing of visually presented words by primary school pupils who had only formed, but not yet automated, the decoding system for semantic information. It would also be useful to collect information on the contour of interhemispheric functional interaction, and to render this factor as a dependent variable when taking into account the quantitative indices of perception of SS.

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