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Posted Date: 4 October 2023

doi: 10.20944/preprints202310.0178.v1

Keywords: aphasia; time reference; tense; encoding; retrieval; Greek; Russian; Italian; English



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Article

Teasing Apart Tense-Related Encoding and Retrieval Deficits in Aphasia: Evidence from Greek, Russian, Italian and English

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Abstract: Persons with stroke-induced aphasia (PWAs) are often impaired in tense/time reference (TR) production. It is not clear, however, whether PWAs' impaired TR production is due to TR-related encoding or retrieval deficits. This study aims at disentangling TR-related encoding deficits from TR-related retrieval deficits in aphasia. Two sentence completion tasks (SCTs) tapping production of past and future reference were administered to eight Greek-speaking PWAs, eight Russian-speaking PWAs, six Italian-speaking PWAs, seven English-speaking PWAs and four groups of language-, age- and education-matched healthy controls. SCT 1 tapped TR-related encoding processes and TR-related retrieval processes to a similar extent. SCT 2 predominantly tapped TR-related retrieval processes. All four control groups performed at ceiling. Three Greek-speaking PWAs, one Russian-speaking PWA, three Italian-speaking PWAs and two English-speaking PWAs showed between-task dissociations. A double dissociation emerged, as some Greek-, Russian- and English-speaking PWAs performed better on SCT 1 than on SCT 2, whereas other Greek- and Italian-speaking PWAs performed worse on SCT 1 than on SCT 2. It will be shown that the experimental design employed here has the potential to disentangle TR-related encoding deficits from TR-related retrieval deficits, as both PWAs with selective TR-related encoding deficits and PWAs with selective TR-related retrieval deficits were identified.

Keywords: aphasia; time reference; tense; encoding; retrieval; Greek; Russian; Italian; English

Introduction

A thorough, reliable and valid neuropsychological assessment can inform the clinician about the linguistic and cognitive strengths and weaknesses of individuals with language disorders, which in turn can inform treatment programs tailored to the specific needs of each client. We consider psycholinguistic assessment to be part of neuropsychological assessment. In this study, we focus on verb-related morphosyntactic/morphosemantic assessment. Specifically, we focus on production of time reference (TR)/tense, which is often impaired in persons with stroke-induced aphasia (PWAs) (e.g., Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Fyndanis et al., 2018b; Kok et al., 2007; Wenzlaff & Clahsen, 2004). Moreover, PWAs often exhibit dissociations between past and non-past reference (e.g., Bastiaanse et al., 2011; Fyndanis et

al., 2018a; Nerantzini et al., 2020). This seems to be the case in both nonfluent and fluent aphasia (e.g., Fyndanis et al., 2018a). In a number of studies on TR in different languages, Bastiaanse and colleagues (e.g., Bastiaanse, 2008; Bastiaanse et al., 2011; Dragoy & Bastiaanse, 2013; Martínez-Ferreiro & Bastiaanse, 2013; Yarbay Duman & Bastiaanse, 2009) found that, in aphasia, reference to the past is more prone to impairment than reference to the present or future. To account for this pattern, Bastiaanse et al. (2011) proposed the PAsT DIscourse LInking Hypothesis (PADILIH), which states that reference to the past is more demanding than reference to the non-past (i.e., present and/or future) because it involves discourse linking (Zagona, 2003, 2013). However, not all aphasia studies on TR provided empirical evidence for the PADILIH. For example, some studies on Greek aphasia that tested production of TR with sentence completion tasks found no difference between production of past and future reference at the group level (e.g., Fyndanis et al., 2018a; Nerantzini et al., 2020; Koukoulioti & Bastiaanse, 2020). Interestingly, Fyndanis et al. (2018a) reported a double dissociation between past reference and future reference in their Greek-speaking PWAs, as some participants performed better on the production of past reference than on the production of future reference, and others exhibited the opposite pattern. That is, the former PWAs produced more future reference errors (e.g., **Tomorrow Mary ate an ice-cream*) than past reference errors (e.g., **Yesterday Mary will eat an ice-cream*), and the latter PWAs produced more past reference errors than future reference errors. It is not yet clear whether the TR impairments in PWAs are due to TR-related encoding deficits or due to TR-related retrieval deficits (or due to both). Some PWAs may predominantly have encoding deficits, and other PWAs may predominantly have retrieval deficits. Some others may have encoding and retrieval deficits to a similar extent.

Encoding and retrieval are two major components of the TR process (see, among others, Bock & Levelt, 2002; Levelt, 1999). For instance, to refer to an event (e.g., *cooking*) that took place before the utterance time, the speaker must *encode* the abstract prephonological feature (i.e., PAST) of the to-be-produced verb (*to cook*). Subsequently, they have to *retrieve* the corresponding phonological form of the verb (i.e., *cooked*).

The double dissociation between past reference and future reference reported in Fyndanis et al. (2018a) was interpreted as suggesting that different sources of difficulty differentially affect the ability of PWAs to refer to the past or to the future. Such sources may include the semantic components of TR¹, language-specific morphological means of encoding past and futurereference, PWAs' selective deficits in TR-related encoding or retrieval processes, and others. Fyndanis et al. (2018a) noted that the bulk of the supporting evidence for the PADILIH (Bastiaanse et al., 2011) has been provided by studies employing the Test for Assessing Reference of Time (TART) (Bastiaanse et al., 2008), which is a task that predominantly investigates the participant's ability to retrieve the verb form that corresponds to a given time frame². In contrast, the transformational sentence completion task used in Fyndanis et al. (2018a) tapped encoding and retrieval to a similar extent. Fyndanis et al. (2018a) argued that the contradictory results reported in their study and in studies employing the TART (e.g., Bastiaanse et al., 2011; Dragoy & Bastiaanse, 2013; Martínez-Ferreiro & Bastiaanse, 2013; Tsiwah et al., 2021) "could be reconciled by hypothesizing that in the retrieval phase past reference is more demanding in terms of processing resources than future reference, and in the encoding phase future reference is more difficult than past reference. If the two major processes involved in time reference exhibit opposing patterns of selective difficulty, and assuming that some individuals with aphasia have encoding or retrieval problems only and some have mixed difficulties, opposing dissociations between past and future reference could cancel each other out at the group level, [...] if similar numbers of speakers with a selective encoding deficit and of speakers with a selective retrieval deficit were included in the group of participants with aphasia. [...] Evidence for the hypothesis would be provided by finding that the participants with a selective retrieval deficit are more impaired in past reference than in future reference, and those with a selective encoding deficit are more impaired in future reference than in past reference" (p. 838). Lastly, Fyndanis et al. (2018a) proposed that, to disentangle selective TR-related encoding deficits from selective TR-related retrieval deficits, "an experimental paradigm would have to include a transformational sentence completion task [...] and a task similar to the TART (Bastiaanse et al., 2008). Since the transformational sentence

completion task taps into encoding and retrieval processes to a similar extent, whereas the TART predominantly involves retrieval processes, participants with selective encoding problems should fare significantly better on the TART than on the transformational sentence completion task, and participants with a selective deficit in retrieval processes should perform equally poorly on the two tasks" (p. 838).

Following up on Fyndanis et al.'s (2018a) study, the present study aims at teasing apart TR-related encoding processes and TR-related retrieval processes, identifying selective TR-related encoding or/and retrieval deficits in PWAs. Relatedly, it addresses whether there are task effects when exploring TR production with constrained tasks. Moreover, the study tests Fyndanis et al.'s (2018a) speculation that PWAs with selective TR-related retrieval deficits might be more impaired in past reference than in future reference, and PWAs with selective TR-related encoding deficits might be more impaired in future reference than in past reference.

Background on time reference in Greek, Russian, Italian and English

In all four languages, TR is made through verb inflection and temporal adverbials. As shown in Table 1, reference to the past (for both perfective and imperfective verbs) through verb inflection is predominantly expressed by monolectic verb forms in Greek and Russian, and by both monolectic and periphrastic verb forms in English and spoken Italian in Northern Italy, which is relevant here. On the other hand, reference to the future is predominantly made via monolectic verb forms in Italian, and via periphrastic verb forms in Greek (where a finite nonpast verb form is preceded by the particle *tha*) and English (where a nonpast verb form is preceded by the modal verb *will*). In Russian, both monolectic and periphrastic forms referring to the future are possible: future-referring monolectic verb forms encode perfective aspect, whereas future-referring periphrastic verb forms encode imperfective aspect. The latter forms consist of the auxiliary verb *быть* 'to be' in the future tense and the infinitival form of a verb (with the former preceding the latter).

Materials and Methods

Two sentence completion tasks tapping TR and subject-verb Agreement production were administered to eight Greek-speaking PWAs (four female, $M_{age} = 63.9$ years, $SD = 7.6$, range 51-

76 years; M number of years of formal education = 11.6, $SD = 5.4$, range 2-19), eight Russian-speaking PWAs (seven female; $M_{age} = 57.6$ years, $SD = 9.6$, range 45-74 years; M number of years of formal education = 14, $SD = 2.2$, range 11-18), six Italian-speaking PWAs (all male, $M_{age} = 54.8$, $SD = 4.1$, range 48-60 years; M number of years of formal education = 11.5, $SD = 2.7$, range 8-14), seven English-speaking PWAs (two female, $M_{age} = 57.4$ years, $SD = 12.0$, range 35-71 years; M number of years of formal education = 14.7, $SD = 2.9$, range 12-20) and four groups of language-, age- and education-matched healthy controls. Task 1 was a transformational sentence completion task tapping TR-related encoding and TR-related retrieval processes to a similar extent, and Task 2 was a non-transformational sentence completion task predominantly tapping TR-related retrieval processes (for examples, see Table 6). Both tasks tapped into production of past reference and future reference. Since subject-verb Agreement has been consistently found to be better preserved than TR in aphasia (e.g., Friedmann & Grodzinsky, 1997; Gavarró & Martínez-Ferreiro, 2007; Fyndanis et al., 2018b; Wenzlaff & Clahsen, 2004), it was included as a control condition. That is, although this study focuses on TR, participants' performance on Agreement will also be reported, as potential task effects that do not relate to encoding and retrieval processes will be easier to be determined if they appear in both the more demanding and less demanding conditions.

Table 1. Past and future reference in Greek, Russian, Italian and English (for the 1st person, singular number, indicative mood of the verb *κλείνω* /*klíno*/, *zakryvat'*, *giocare*, *play* 'play').

	Greek	Russian	Italian	English
Past Reference	ékliśa (ékliŋa)	zakryval (zakryl)	ho chiuso (chiudevo/chiusi)	closed (was closing)

Future Reference	θα κλίσο (θα κλίνο)	budet zakryvat' (zakroet/ zakryvayu)	chiuderó (chiudo)	will close (will be closing/am closing)
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Note: In Italian, present tense (e.g. *chiudo*) is often used to refer to the future in the presence of a temporal adverbial (e.g. *Domani (io) chiudo... Tomorrow (I) close... (lit.) 'Tomorrow I am closing.../Tomorrow I will close...'*). The difference between the Greek verb forms *ékliśa* and *éklińa*, and between *θα κλίσο* and *θα κλίνο* reflects the opposition between perfective and imperfective aspect, respectively. Likewise, the Italian verb forms *ho chiuso/chiusi* and *chiudevo*, and the English verb forms *closed* and *was closing* encode perfective and imperfective aspect, respectively. In Russian, imperfective (*zakryvat'*) and perfective (*zakryt'*) verbs have different paradigms. In the past tense, both of them have monolectic forms (*zakryval/zakryl*). Future reference can be expressed via periphrastic verb forms (*budet zakryvat'*), which encode imperfective aspect, or monolectic verb forms (*zakroet*), which encode perfective aspect. At the same time, the present tense (*zakryvayu*) can be used to refer to future events, similar to Italian.

The study was approved by the Norwegian Centre for Research Data, the Cyprus National Bioethics Committee, the Ethical Committee of the Center for Speech Pathology and Neurorehabilitation (Moscow, Russia), the Ethics Committee for clinical experimentation of Venice and IRCCS San Camillo Hospital (Venice, Italy), and the Institutional Review Board for the Charles River Campus at Boston University (Boston, USA). All participants took part in the study on a voluntary basis and gave informed consent in accordance with the Declaration of Helsinki.

Both persons with non-fluent aphasia and persons with fluent aphasia took part in the study. In all PWAs, aphasia resulted from a single left-hemisphere stroke. All PWAs had well-preserved auditory comprehension abilities and no or mild dysarthria or apraxia of speech. Furthermore, they all had (corrected to) normal vision and hearing, and none of them had a history of neurological or psychiatric disorders, traumatic brain injuries or alcohol/drug abuse.

All eight Greek-speaking PWAs were diagnosed with chronic aphasia (M time post-onset = 41.3 months, SD = 13.4, range = 17-62 months). In particular, based on clinical presentation and the published Greek standardized version of the Boston Diagnostic Aphasia Examination-Short Form (BDAE-SF) (Goodglass et al., 2001; Greek version by Messinis et al., 2013), five participants were diagnosed with non-fluent aphasia (three participants with Broca's aphasia and one with transcortical motor aphasia) and three with fluent aphasia. A standardized Greek version of the Montreal Cognitive Assessment (MoCA) (Poptsi et al., 2019) was administered to healthy controls older than 60 years to exclude participants with signs of dementia. Table 2 summarizes the available demographic and clinical information about the Greek-speaking participants.

Of the eight Russian-speaking PWAs, six were diagnosed with chronic aphasia (post-onset range: 39-110 months) and two with subacute aphasia (post-onset range: 3-4 months). For the entire group of Russian-speaking PWAs, the mean time post-onset was 55.4 months (SD = 39.4, range = 3-110 months). Prior to their inclusion in the study, a professional speech/language therapist (SLT) examined all PWAs with the scale for assessing the severity of speech disorders in individuals with local brain damage (Vasserman et al., 1997). The severity of aphasia was scaled from 0 to 7 where 0 indicates absence of deficit, and 7 corresponds to a very severe impairment ($M_{severity}$ = 4.25, SD = 0.89, range = 3-6). Aphasia types were defined according to Luria's aphasia classification (for review, see Akhutina, 2016). Only individuals diagnosed with the primary non-fluent aphasia types (i.e., efferent motor, complex motor or dynamic aphasia) participated in the study. All participants underwent standard clinical MRI. The information about lesion location was based on the radiologists' report. Russian-speaking participants' detailed clinical and demographic information is presented in Table 3.

The mean time post stroke for the Italian-speaking PWAs was 37.5 months (SD = 22.5; range = 13-61 months). Aphasia type was determined by a clinical assessment made by an expert SLT using the Aachen Aphasia Test (Luzzatti et al., 1996). Four patients were diagnosed with Broca's aphasia (following a left ischemic lesion [$N=2$] or a left hemorrhagic lesion [$N=2$]), and two with mixed transcortical aphasia (following a left hemorrhagic lesion). The background information for the Italian-speaking participants is presented in Table 4. Healthy controls were recruited by contacting patients' family members or through adverts. An Italian version of the MoCA (Santangelo et al., 2015)

was administered to healthy controls older than 60 years to exclude participants with signs of cognitive impairment.

The American English-speaking PWAs and healthy controls were recruited from existing participant databases in Center for Brain Recovery at Boston University. All PWAs were diagnosed with chronic aphasia (M time post-onset = 96.3 months, SD = 51.6, range = 24-162 months) by SLTs. The Western Aphasia Battery-Revised (WAB-R, Kertesz, 2007) was used to quantify severity and classify aphasia subtype. Based on the WAB-R, six participants were diagnosed with fluent profiles of aphasia and one with a non-fluent profile. The English version of the MoCA (Nasreddine et al., 2005) was administered to healthy controls 60 years and older to exclude participants with evidence of cognitive impairment. Both the PWAs and healthy controls denied any history of pre-morbid neurological conditions or learning disabilities which could have affected their performance on the cognitive-linguistic assessments. Additionally, both groups presented with normal or corrected-to-normal hearing and vision (see note in Table 5 about EP7). Detailed clinical and demographic information is available in Table 5.

In all four testing sites (Thessaloniki, Greece; Moscow, Russia; Lido/Venice, Italy; and Boston, USA), all participants were tested individually in a quiet environment by a clinical linguist (in Moscow) or an SLP (in Thessaloniki and Lido/Venice) or a trained psycholinguist or clinical fellow (in Boston). First, they were administered the non-transformational sentence completion task (Task 2), and then they completed the transformational sentence completion task (Task 1). Each participant completed one of the two stimuli lists of each task. The experimental lists were assigned to the participants in a pseudorandomized order.

In Task 1, participants were auditorily presented with a source sentence (e.g., *Yesterday the man watered the flowers*) and the beginning of a target sentence (e.g., *Tomorrow the man...*). They were required to complete the target sentence producing the correct form of the verb phrase included in the source sentence (i.e., *will water the flowers*) (for examples, see Table 6). In the TR condition of this task, the participant had to encode a different TR-related abstract, prephonological value than that of the verb form that appeared in the source sentence, and then to retrieve a phonological form that matched the target prephonological TR-related value; the target phonological form of the verb, thus, always differed from the phonological form included in the source sentence. Task 1, therefore, appears to engage encoding and retrieval processes to a similar extent.

In Task 2, participants were cross-modally presented with the citation form of the target verb and its internal argument (i.e., object). The citation forms used were verb forms in 1st person, singular number, present tense and active voice in the Greek version of Task 2 (e.g., ψήνω μπισκότα ‘bake-1st.sg.present cookies’), and the infinitival forms of the target verb in the Russian, Italian and English versions of Task 2 (e.g., *bake cookies*; see also Table 6 and Table 7). Subsequently, participants were auditorily presented with a source sentence (e.g., *Tomorrow the man will water the flowers*) and the beginning of a target sentence (e.g., *Tomorrow the man...*) (for more examples, see Table 6 and Table 7), and were instructed to complete the target sentence producing the correct form of the verb phrase appearing on the computer screen

Table 2. Greek-speaking PWAs’ and control participants’ background information.

	GP1	GP2	GP3	GP4	GP5	GP6	GP7	GP8	Group of PWAs (N=8) (Mean (SD))	Control group (N=8) (Mean (SD))
Sex	M	M	F	F	F	F	M	M	4F, 4M	6F, 2M
Age (years)	67	57	64	65	69	76	62	51	63.9 (7.6)	63.8 (6.9)
Education (years)	14	11	16	13	6	2	19	12	11.6 (5.4)	12.2 (4.2)
Handedness	R	L	R	R	R	R	L	R	6 R, 2 L	7 R, 1 L
Etiology	L CVA	L CVA	L CVA	L CVA	L CVA	L CVA	L CVA	L CVA	n.a.	n.a.
Aphasia post-onset (months)	62	45	45	44	42	17	28	47	41.3 (13.4)	n.a.
Other conditions	Right hemiparesis	Right hemiparesis	Right hemiplegia	Very mild right	n.a.	Mild right hemiparesis	No	Right hemiplegia	n.a.	No

hemiparesis											
Hearing & Vision	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	Normal or corrected to normal	n.a.	Normal or corrected to normal
Diagnosis	Nonfluent aphasia (Broca's aphasia)	Nonfluent aphasia (Broca's aphasia)	Nonfluent aphasia (Transcortical motor aphasia)	Nonfluent aphasia (Broca's aphasia)	Nonfluent aphasia (unclassifiable)	Fluent aphasia (unclassifiable)	Fluent aphasia (unclassifiable)	Fluent aphasia (unclassifiable)	Fluent aphasia (unclassifiable)	5 nonfluent aphasia, 3 fluent aphasia	n.a.
Lesion site	Not available	Not available	Not available	Not available	Not available	Parietal lobe	Not available	Not available	Not available	n.a.	n.a.

Note: GP = Greek-speaking participant with aphasia; SD = Standard Deviation; M = Male; F = Female; CVA = Cerebrovascular Accident; n.a. = not applicable; R = Right; L = Left.

Table 3. Russian-speaking PWAs' and control participants' background information.

	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RP8	Group of PWAs (N=8) (Mean (SD))	Control group (N=11) (Mean (SD))
Sex	M	F	F	F	F	F	F	F	7F, 1M	3M, 8F
Age (years)	57	47	64	61	45	52	74	61	57.6 (9.6)	58.2 (8.9)
Education (years)	11	12	13	15	15	13	15	18	14 (2.2)	15.8 (3.0)
Handedness	R	R	R	R	R	R	R	R	All R	All R
Etiology	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	Left hemorrhagic CVA	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	n.a.	n.a.
Aphasia post-onset (months)	110	39	4	82	43	3	77	85	55.4 (39.4)	n.a.
Other conditions	Moderate right hemiparesis	Right-sided hemihyesthesia	No	Mild right hemiparesis	Severe right hemiparesis	Right hemiparesis	No	No	n.a.	n.a.
Hearing/Vision	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Corrected to normal	Normal/Normal or corrected to normal	Normal or corrected to normal
Diagnosis	Mild-moderate efferent motor aphasia; dysarthria	Moderate-severe complex motor aphasia and dynamic aphasia	Moderate efferent motor aphasia	Moderate complex motor aphasia	Moderate complex motor aphasia	Moderate complex motor aphasia	Severe complex motor aphasia; dysarthria	Moderate efferent motor aphasia with elements of sensory aphasia	n.a.	n.a.
Lesion site	Left fronto-temporal regions and the basal ganglia	Left fronto-temporal regions (IFG, STG, insula)	Left frontal, cortical and subcortical	Left fronto-temporo-parietal	Left insula and basal ganglia	Left frontal and parietal regions	Left fronto-temporo-parietal	Left fronto-temporo-parietal	n.a.	n.a.

RP = Russian-speaking participant with aphasia; SD = Standard Deviation; M = Male; F = Female; CVA = Cerebrovascular Accident; n.a. = not applicable; R = Right; L = Left.

Table 4. Italian-speaking PWAs' and control participants' background information.

	IP1	IP2	IP3	IP4	IP5	IP6	Group of PWAs (Mean (SD))	Control group (N=7) (Mean (SD))
Sex	M	M	M	M	M	M	6M	4F, 3M
Age (years)	53	56	60	48	55	57	54.8 (4.1)	59.0 (4.6)
Education (years)	8	13	13	8	13	14	11.5 (2.7)	14.4 (2.3)
Handedness	R	R	R	R	R	R	All R	All R
Etiology	Left ischemic	Left hemorrhagic	Left hemorrhagic	Left	Left hemorrhagic	Left ischemic	n.a.	n.a.

	CVA	CVA	CVA	hemorrhagic CVA	CVA	CVA		
Aphasia post-onset (months)	13	15	24	61	54	58	37.5 (22.5)	n.a.
Other conditions	Mild right hemiparesis	Right hemiplegia	Very mild right hemiparesis	Mild right hemiparesis	Right hemiplegia	Mild right upper hemiparesis	n.a.	No
Hearing/Vision	Normal/Normal	Normal/Normal	Normal/Corrected to normal	Normal/Corrected to normal	Corrected to normal/Corrected to normal	Normal/Normal	Normal or corrected to normal	Normal or corrected to normal
Diagnosis	Broca's aphasia	Broca's aphasia	Mixed transcortical aphasia	Mixed transcortical aphasia	Broca's aphasia	Broca's aphasia	n.a.	n.a.
Lesion site	Left fronto-parietal-insular cortico-subcortical regions	Left fronto-temporal cortex	Left fronto-temporo-parietal cortex	Left temporal cortex; left capsular and semioval nuclei	Left parieto-temporal cortical and subcortical regions	Left fronto-temporo-parietal cortical and subcortical regions	n.a.	n.a.

IP = Italian-speaking participant with aphasia; SD = Standard Deviation; M = Male; F = Female; CVA = Cerebrovascular Accident; n.a. = not applicable; R = Right; L = Left.

Table 5. English-speaking PWAs' and control participants' background information.

	EP1	EP2	EP3	EP4	EP5	EP6	EP7	Group of PWAs (N=7) (Mean (SD))	Control group (N=7) (Mean (SD))
Sex	M	M	F	M	M	F	M	2F, 5M	5F, 2M
Age (years)	59	71	56	68	62	51	35	57.4 (12.0)	64.0 (8.3)
Education (years)	12	13	17	12	14	20	15	14.7 (2.9)	18 (2.8)
Handedness	R	L	R	R	R	L	R	5 R, 2L	All R
Etiology	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	Left ischemic CVA	Left hemorrhagic CVA	n.a.	n.a.
Aphasia post-onset (months)	161	92	69	59	107	24	162	96.3 (51.6)	n.a.
Other conditions	Right hemiplegia	Right-sided weakness	Right hemiparesis	Right-sided weakness	Right hemiparesis	Right hemiparesis	Right hemiparesis; hemianopsia*	n.a.	n.a.
Hearing & Vision	Normal/Corrected to Normal	Normal/Normal	Normal/Normal	Normal/Corrected to Normal	Corrected to Normal/Corrected to Normal	Normal/Normal	Normal/Impaired*	n.a.	n.a.
Diagnosis	Anomic aphasia	Anomic aphasia; dysarthria	Transcortical sensory aphasia	Anomic aphasia; apraxia	Broca's aphasia; dysarthria	Anomic aphasia	Anomic aphasia	6 fluent aphasia, 1 nonfluent aphasia	n.a.
Lesion site	Left anterior temporal and inferior frontal	Left temporal regions and basal ganglia	Left middle cerebral artery territory	Left periventricular white matter and basal ganglia	Left parietal and superior temporal lobes, insular cortex, and caudate nucleus	Left frontal lobe, insula, and basal ganglia	Left sylvian fissure	n.a.	n.a.

EP = English-speaking participant with aphasia; SD = Standard Deviation; M = Male; F = Female; CVA = Cerebrovascular Accident; n.a. = not applicable; R = Right; L = Left; *EP7 compensated for hemianopsia (25-50% reduction of inner visual field in each eye) throughout testing by turning head and fixating written stimuli with ease.

Table 6. Examples of the Past Reference (sub)condition of the Greek, Russian, Italian and English versions of the transformational sentence completion task (Task 1) and the non-transformational sentence completion task (Task 2).

Task 1	Past Reference
Source Sentence	GR: Οι κηπουροί αύριο θα ποτίσουν τα λουλούδια.

	<p>'The gardeners tomorrow will water the flowers (lit.)' RU: Садовник завтра польет растения 'Gardener-<i>definitive</i> tomorrow water-<i>future-perfective</i> plants-<i>definitive</i> (lit.)' IT: I giardinieri domani bagneranno i fiori. 'The gardeners tomorrow water-<i>future</i> the flowers (lit.)' EN: Tomorrow the man will water the flowers. GR: Οι κηπουροί χθες _____ 'The gardeners yesterday _____ (lit.)' (target: <i>πότισαν τα λουλούδια</i> 'watered the flowers') RU: Садовник вчера _____ 'Gardener-<i>definitive</i> yesterday _____ (lit.)' (target: <i>полил растения</i> 'watered plants-<i>definitive</i> (lit.)') IT: I giardinieri ieri _____ 'The gardeners yesterday _____ (lit.)' (target: <i>hanno bagnato i fiori</i> 'watered the flowers') EN: Yesterday the man _____. (target: <i>watered the flowers</i>)</p>
Task 2	Past Reference
Source Sentence	<p>GR: [ποτίζω τον κήπο 'water the garden'] Οι κηπουροί χθες έσκαψαν τον κήπο. 'The gardeners yesterday dug the garden (lit.)' RU: [полить растения 'water plants'] Садовник вчера полил растения 'Gardener-<i>definitive</i> yesterday watered plants (lit.)' IT: [bagnare i fiori 'water the flowers'] I giardinieri ieri hanno zappato l'orto. 'The gardeners yesterday have dug the garden (lit.)' EN: [water the flowers] Yesterday the man baked cakes.</p>
Target Sentence	<p>GR: Οι κηπουροί χθες _____ 'The gardeners yesterday _____' (target: <i>πότισαν τον κήπο</i> 'watered the garden') RU: Садовник вчера _____ 'Gardener-<i>definitive</i> yesterday _____' (target: <i>полил растения</i> 'watered plants-<i>definitive</i>') IT: I giardinieri ieri _____ 'The gardeners yesterday _____ (lit.)' (target: <i>hanno bagnato i fiori</i> 'have watered the flowers (lit.)') EN: Yesterday the man _____. (target: <i>watered the flowers</i>)</p>

Table 7. Examples of the subject-verb Agreement condition of the Greek, Russian, Italian and English versions of the transformational sentence completion task (Task 1) and the non-transformational sentence completion task (Task 2).

Task 1	Agreement
Source Sentence	<p>GR: Αύριο εγώ θα ποτίσω τα λουλούδια. 'Tomorrow I will water the flowers' RU: Сейчас мы поливаем растения 'Now we water-<i>1st.pl.present-imperfective</i> plants-<i>definitive</i> (lit.)' IT: Domani io bagnerò i fiori. 'Tomorrow I water-<i>1st.sg.future</i> the flowers (lit.)' EN: Everyday I water the flowers.</p>
Target Sentence	<p>GR: > Αύριο ο κηπουρός _____.</p>

	<p>'Tomorrow the gardener _____.'</p> <p>(target: <i>θα ποτίσει τα λουλούδια</i> 'will water the flowers')</p> <p>RU: Сейчас садовники _____</p> <p>'Now gardeners-definitive _____'</p> <p>(target: <i>поливают растения</i> 'water-3rd.pl.present-imperfective plants-definitive')</p> <p>IT: Domani il giardiniere _____.</p> <p>'Tomorrow the gardener _____.'</p> <p>(target: <i>bagnerà i fiori</i> 'water-3rd.sg.future the flowers (lit.)')</p> <p>EN: Everyday the aunt _____.</p> <p>(target: <i>waters the flowers</i>)</p>
Task 2	Agreement
Source Sentence	<p>GR: [ποτίζω τα λουλούδια 'water the flowers']</p> <p>Αύριο ο κηπουρός θα σκάψει τον κήπο.</p> <p>'Tomorrow the gardener will dig the garden'</p> <p>RU: [поливать растения 'water plants']</p> <p>Сейчас садовники поливают растения</p> <p>'Now gardeners-definitive water-3rd.pl.present-imperfective plants'</p> <p>IT: [bagnare i fiori 'water the flowers']</p> <p>Domani il giardiniere zapperà l'orto.</p> <p>'Tomorrow the gardener will hoe the garden'</p> <p>EN: [water the flowers]</p> <p>Everyday the aunt bakes cakes.</p>
Target Sentence	<p>(target: <i>ποливают растения</i> 'water-3rd.pl.present-imperfective plants-definitive (lit.)')</p> <p>IT: Domani il giardiniere _____.</p> <p>'Tomorrow the gardener _____.'</p> <p>(target: <i>bagnerà i fiori</i> 'water-3rd.sg.future the flowers (lit.)')</p> <p>EN: Everyday the aunt _____.</p> <p>(target: <i>waters the flowers</i>)</p>

(i.e., *will bake cookies*). Therefore, in the TR condition of Task 2, the participant had to 'copy and paste' the TR-related prephonological feature (e.g., +FUTURE) from the source sentence to the target sentence and then to retrieve the corresponding verb form. Therefore, Task 2 posed fewer encoding demands on the speaker's processing system than Task 1, and predominantly tapped into retrieval processes.

Both tasks included 40 items tapping into TR production, of which 20 tapped past reference and 20 future reference. Task 1 and Task 2 also included 40 and 20 items tapping into subject-verb Agreement, respectively (for examples, see Table 7). Either task was split into two lists, and each participant completed one list.

Twenty regular transitive verbs taking one external and one internal argument (subject/agent and object/theme, respectively) were used in each language version of Task 1. All verbs were in active voice, and each verb appeared four times in Task 1. Specifically, in the TR condition, each verb appeared once in a past reference item (e.g., *Tomorrow the seamstress will iron the socks* > *Yesterday the seamstress ironed the socks*) and once in a future reference item (e.g., *Yesterday the seamstress ironed the socks* > *Tomorrow the seamstress will iron the socks*); in the subject-verb Agreement condition, each verb appeared once in a person agreement item (e.g., *Every day I iron the socks* > *Every day the seamstress irons the socks*) and once in a number agreement item (e.g., *Every day the seamstresses iron the socks* > *Every day the seamstress irons the socks*). In the Greek and Italian versions of Task 1, subject-verb

Agreement was tested within past reference and future reference contexts. In the Russian and English versions, however, subject-verb Agreement was tested only within a present tense/reference context, as in English the person and number features are not marked morphologically on past-and future-tensed verb forms, and in Russian, only present-tensed and future-tensed verbs morphologically mark *both* person and number features³In present tense, there are only imperfective verbs in Russian; therefore, we used only imperfective verbs for the stimuli tapping into subject-verb Agreement. However, in the TR condition we used perfective verbs only, because the usage of present imperfective verb forms in future reference contexts, although plausible, could lead to ambiguous results. In all language versions of Task 1, all target verb forms in the Agreement condition were in 3rd person in order to avoid conversation-type errors (see Fyndanis et al., 2013).⁴ In the Agreement condition of the English Task 1, all experimental pairs tapping person agreement included transitions from 1st person and singular number to 3rd person and singular number. Transitions from verb forms in 2nd person and singular number to verb forms in 3rd person and singular number were not included, because the “2nd person cue” in English (*you*) is ambiguous (i.e., same for both singular and plural). Finally, all experimental pairs tapping number agreement in the English Task 1 included transitions from 3rd plural to 3rd singular. In contrast, the number agreement (sub)conditions in the Greek, Russian and Italian versions of Task 1 included both transitions from 3rd plural to 3rd singular and transitions from 3rd singular to 3rd plural. The experimental items instantiating these two transition types were evenly distributed within the number agreement (sub)conditions of the Greek, Russian and Italian versions of Task 1. Furthermore, unlike in the English Task 1, person agreement in the Greek, Russian and Italian versions of Task 1 was tested within both singular and plural number.

The same 20 verbs that were included in Task 1 were also used in Task 2. However, in Task 2, each of these verbs appeared three times: twice in the TR condition (once in a past reference item, and once in a future reference item) and once in the subject-verb Agreement condition. (Due to the non-transformational nature of Task 2, it was not possible to distinguish between person agreement and number agreement.)

In both Task 1 and Task 2, the TR items were pseudorandomly interspersed with the Agreement items. The order of items was kept constant for all participants.

The rationale behind this experimental design is reflected in (1) – (3).

- 1) Worse performance on Task 1 than on Task 2 will point to a selective deficit in TR-related encoding processes.
- 2) Comparably poor performance on Task 1 and Task 2 will point to selective deficit in TR-related retrieval processes
- 3) Better performance on Task 1 than on Task 2 will point to task effects unrelated to encoding and retrieval processes

Scoring criteria

In the TR conditions, all responses including verb forms matching the target time frame were scored as correct. Since aspectual adverbials were not included in the experimental items, responses including verb forms that matched the target time frame were scored as correct irrespective of the aspectual value they encoded. Likewise, in the subject-verb Agreement conditions, all responses including verb forms matching the target person and number were scored as correct. However, the scoring criteria for the Agreement condition in the English Task 1 and Task 2 are less straightforward. In the English tasks, all target sentences in this condition included verb forms in 3rd person, singular number and present tense. Some English-speaking PWAs, however, often produced verb forms in past or future tense, where subject-verb agreement is not marked overtly. When producing such verb forms in English, therefore, it is impossible to make agreement errors. Given this feature of the English morphology, we used two methods of scoring English-speaking participants’ responses in the Agreement conditions. In scoring method 1, we did not remove any response and scored as incorrect responses only those responses that included uncontroversial agreement errors. In other words, responses that included verb forms in past tense (i.e., verb forms ending in *-ed* in the current tasks) or future tense (will + base infinitival forms⁵ of verbs) were always scored as correct. In scoring

method 2, we removed all responses that included verb forms in tenses where subject-verb agreement is not encoded overtly. As will be shown in the Results section (see Table 8), for all but one English-speaking PWA, the results of the comparisons between Task 1 and Task 2 in the Agreement condition were not affected by the choice of the scoring method.

Results

All four control groups performed at ceiling. As shown in Table 8, in the TR condition, three Greek-speaking PWAs (GP1, GP4 and GP6), one Russian-speaking PWA (RP6), three Italian-speaking PWAs (IP3, IP4 and IP6) and two English-speaking PWAs (EP5 and EP7) showed between-task dissociations. A double dissociation emerged, as GP1, GP6, RP6, EP5 and EP7 performed better on Task 1 than on Task 2, whereas GP4, IP3, IP4 and IP6 performed worse on Task 1 than on Task 2. In the Agreement condition, eight-to-nine PWAs (namely, GP1, GP2, RP3, RP6, IP5, (EP1),⁶ EP4, EP5 and EP6) exhibited between-task dissociations that had the same direction: Task 2 elicited worse performances than Task 1.

Furthermore, as shown in Table 9, dissociations between past and future reference were exhibited by GP1 (in Task 2), GP4 (in Task 1), GP5 (in Task 1), GP6 (in Task 1), RP3 (in Task 1), IP1 (in Task1), IP4 (in Task 2), IP6 (in Task 1), EP3 (in both tasks) and EP7 (in Task 1). In fact, a double dissociation between past and future reference emerged, as GP1, GP4, GP5, GP6, RP3, EP3 and EP7 fared better on past reference than on future reference, whereas IP1, IP4 and IP6 exhibited the opposite pattern.

Discussion

The primary goal of the present study was to tease apart selective TR-related encoding deficits and TR-related retrieval deficits in PWAs. To this end, we administered two sentence completion tasks tapping production of past reference, future reference and subject-verb Agreement (with the latter serving as a control condition) to Greek-speaking, Russian-speaking, Italian-speaking and English-speaking PWAs. Task 1 was a transformational sentence completion task tapping encoding and retrieval processes to a similar extent, whereas Task 2 was a non-transformational.

Table 8. PWAs' accuracy performance on production of Time Reference and Agreement in Task 1 and Task 2, and within-participant comparisons using the Fisher exact test for count data.

TR-Transf (Task 1)	TR-Nontransf (Task 2)	TR-Transf vs TR- Nontransf	Agr-Transf (Task 1)	Agr-Nontransf (Task 2)	Agr-Transf vs Agr- Nontransf
<i>Greek-speaking PWAs</i>					
GP1 20/20 (100%)	7/20 (35%)	< 0.001*	20/20 (100%)	3/10 (30%)	< 0.001*
GP2 11/20 (55%)	5/20 (25%)	0.105	13/20 (65%)	1/10 (10%)	< 0.01*
GP3 13/20 (65%)	18/20 (90%)	0.127	18/20 (90%)	10/10 (100%)	0.540
GP4 11/20 (55%)	20/20 (100%)	0.001*	19/20 (95%)	10/10 (100%)	1
GP5 10/20 (50%)	10/20 (50%)	1	14/20 (70%)	9/10 (90%)	0.372
GP6 8/20 (40%)	1/20 (5%)	< 0.05*	20/20 (100%)	10/10 (100%)	1
GP7 20/20 (100%)	17/20 (85%)	0.231	20/20 (100%)	10/10 (100%)	1
GP8 17/20 (85%)	14/20 (70%)	0.451	19/20 (95%)	10/10 (100%)	1
<i>Russian-speaking PWAs</i>					
RP1 16/20 (80%)	14/20 (70%)	0.716	20/20 (100%)	9/10 (90%)	0.333
RP2 6/20 (30%)	2/20 (10%)	0.235	11/20 (55%)	4/10 (40%)	0.670
RP3 6/20 (30%)	6/20 (30%)	1	18/20 (90%)	3/10 (30%)	< 0.01*
RP4 7/20 (35%)	14/20 (70%)	0.056	20/20 (100%)	9/10 (90%)	0.333
RP5 18/20 (90%)	16/20 (80%)	0.661	19/20 (95%)	10/10 (100%)	1
RP6 20/20 (100%)	7/20 (35%)	< 0.001*	19/20 (95%)	4/10 (40%)	< 0.01*
RP7 16/20 (80%)	16/20 (80%)	1	20/20 (100%)	10/10 (100%)	1
RP8 11/20 (55%)	9/20 (45%)	0.752	12/20 (60%)	6/10 (60%)	1
<i>Italian-speaking PWAs</i>					
IP1 12/20 (60%)	18/20 (90%)	0.065	17/20 (85%)	6/10 (60%)	0.181
IP2 4/20 (20%)	8/20 (40%)	0.301	14/20 (70%)	4/10 (40%)	0.139

IP3	2/20 (10%)	9/20 (45%)	< 0.05*	8/20 (40%)	6/10 (60%)	0.442
IP4	2/20 (10%)	9/20 (45%)	< 0.05*	4/20 (20%)	1/10 (10%)	0.640
IP5	3/20 (15%)	9/20 (45%)	0.082	16/20 (80%)	2/10 (20%)	< 0.01*
IP6	7/20 (35%)	17/20 (85%)	< 0.01*	13/20 (65%)	8/10 (80%)	0.675
<i>English-speaking PWAs</i>						
EP1	6/20 (30%)	8/20 (40%)	0.741	16/20 (80%)	3/10 (30%)	< 0.05*
				9/13 (69%)	3/10 (30%)	0.100
EP2	7/20 (35%)	7/20 (35%)	1	14/20 (70%)	10/10 (100%)	0.074
				11/17 (65%)	10/10 (100%)	0.057
EP3	11/20 (55%)	6/20 (30%)	0.200	16/20 (80%)	5/10 (50%)	0.116
				3/7 (43%)	1/6 (17%)	0.559
EP4	7/20 (35%)	3/20 (15%)	0.273	16/20 (80%)	2/10 (20%)	< 0.01*
				10/13 (77%)	2/10 (20%)	< 0.05*
EP5	11/20 (55%)	3/20 (15%)	< 0.05*	18/20 (90%)	1/10 (10%)	< 0.001*
				7/8 (88%)	1/10 (10%)	< 0.01*
EP6	3/20 (15%)	6/20 (30%)	0.451	19/20 (95%)	5/10 (50%)	< 0.01*
				15/16 (94%)	5/10 (50%)	< 0.05*
EP7	8/20 (40%)	1/20 (5%)	< 0.05*	18/20 (90%)	10/10 (100%)	0.540
				10/12 (83%)	7/7 (100%)	0.509

Note: In the English Agreement conditions, for each English-speaking PWA, the second row includes accuracy performance based on scoring method 2 (see the Scoring Criteria subsection in the Materials and Methods section).

Table 9. PWAs' accuracy performance on production of Past Reference and Future Reference in Task 1 and Task 2, and within-participant comparisons using the Fisher exact test for count data.

	Past-Transf (Task 1)	Future-Transf (Task 1)	Past-Transf vs Future- Transf (Task 1)	Past-Nontransf (Task 2)	Future-Nontransf (Task 2)	Past-Nontransf vs Future-Nontransf (Task 2)
<i>Greek-speaking PWAs</i>						
GP1	10/10 (100%)	10/10 (100%)	1	7/10 (70%)	0/10 (0%)	< 0.01*
GP2	3/10 (30%)	8/10 (80%)	0.070	1/10 (10%)	4/10 (40%)	0.303
GP3	5/10 (50%)	8/10 (80%)	0.350	10/10 (100%)	8/10 (80%)	0.474
GP4	10/10 (100%)	1/10 (10%)	< 0.001*	10/10 (100%)	10/10 (100%)	1
GP5	8/10 (80%)	2/10 (20%)	< 0.05*	6/10 (60%)	4/10 (40%)	0.656
GP6	7/10 (70%)	1/10 (10%)	< 0.05*	1/10 (10%)	0/10 (0%)	1
GP7	10/10 (100%)	10/10 (100%)	1	9/10 (90%)	8/10 (80%)	1
GP8	8/10 (80%)	9/10 (90%)	1	7/10 (70%)	7/10 (70%)	1
<i>Russian-speaking PWAs</i>						
RP1	7/10 (70%)	9/10 (90%)	0.582	7/10 (70%)	7/10 (70%)	1
RP2	5/10 (50%)	1/10 (10%)	0.141	0/10 (0%)	2/10 (20%)	0.474
RP3	6/10 (60%)	0/10 (0%)	0.011*	2/10 (20%)	4/10 (40%)	0.629
RP4	3/10 (30%)	4/10 (40%)	1	7/10 (70%)	7/10 (70%)	1
RP5	9/10 (90%)	9/10 (90%)	1	7/10 (70%)	9/10 (90%)	0.582
RP6	10/10 (100%)	10/10 (100%)	1	3/10 (30%)	4/10 (40%)	1
RP7	7/10 (70%)	9/10 (90%)	0.582	8/10 (80%)	8/10 (80%)	1
RP8	8/10 (80%)	3/10 (30%)	0.070	7/10 (70%)	2/10 (20%)	0.070
<i>Italian-speaking PWAs</i>						
IP1	3/10 (30%)	9/10 (90%)	< 0.05*	9/10 (90%)	9/10 (90%)	1
IP2	2/10 (20%)	2/10 (20%)	1	4/10 (40%)	4/10 (40%)	1
IP3	0/10 (0%)	2/10 (20%)	0.474	3/10 (30%)	6/10 (60%)	0.370
IP4	0/10 (0%)	2/10 (20%)	0.474	0/10 (0%)	9/10 (90%)	< 0.001*
IP5	2/10 (20%)	1/10 (10%)	1	2/10 (20%)	7/10 (70%)	0.070
IP6	0/10 (0%)	7/10 (70%)	< 0.01*	8/10 (80%)	9/10 (90%)	1
<i>English-speaking PWAs</i>						
EP1	2/10 (20%)	4/10 (40%)	0.629	3/10 (30%)	5/10 (50%)	0.650
EP2	4/10 (40%)	3/10 (30%)	1	6/10 (60%)	1/10 (10%)	0.057
EP3	10/10 (100%)	1/10 (10%)	< 0.001*	6/10 (60%)	0/10 (0%)	< 0.05*
EP4	2/10 (20%)	5/10 (50%)	0.350	3/10 (30%)	0/10 (0%)	0.211
EP5	4/10 (40%)	7/10 (70%)	0.370	3/10 (30%)	0/10 (0%)	0.211
EP6	1/10 (10%)	2/10 (20%)	1	1/10 (10%)	5/10 (50%)	0.141
EP7	8/10 (80%)	0/10 (0%)	< 0.001*	1/10 (10%)	0/10 (0%)	1

completion task predominantly tapping retrieval processes.

We identified both PWAs with selective TR-related encoding deficits and PWAs with selective TR-related retrieval deficits. GP4's, IP3's, IP4's and IP6's significantly worse performance on Task 1 than on Task 2 suggests that these PWAs had selective TR-related encoding problems. This is so because Task 1 tapped into encoding and retrieval processes to a similar extent, whereas Task 2 predominantly tapped into retrieval processes. Therefore, the above PWAs' worse performance on Task 1 than on Task 2 was driven by what distinguishes Task 1 from Task 2, i.e., TR-related encoding demands. RP4, IP1 and IP5 might also have had selective TR-related encoding deficits, as also these participants fared worse on Task 1 than on Task 2, although the between-task differences were marginally significant.

The comparably poor performance of GP2, GP3, GP5, RP2, RP3, RP8, IP2, EP1, EP2, EP3, EP4 and EP6 in the TR condition of the two tasks points to selective deficits in TR-related retrieval processes. This is so because the "common denominator" in Task 1 and Task 2 is the amount of retrieval demands; the two tasks do not differ in retrieval demands.

That GP1, GP6, RP6, EP5 and EP7 performed better on Task 1 than on Task 2 could be accounted for by assuming that, for some participants, Task 2 was harder than Task 1. This is also supported by the fact that eight-to-nine between-task dissociations emerged in the Agreement condition (see results of GP1, GP2, RP3, RP6, IP5, [EP1,] EP4, EP5 and EP6), and all of them had the same direction: Task 2 elicited worse performances than Task 1. It is clear that GP1 and RP6 did not have TR-related encoding or retrieval deficits, as they performed at ceiling in Task 1. Therefore, their patterns of performance in the TR and Agreement conditions should be attributed to task effects unrelated to encoding or retrieval deficits.

Earlier we claimed that GP2's, RP3's, EP1's, EP4's and EP6's comparably poor TR performance on the two tasks points to a selective deficit in TR-related retrieval processes, as both tasks pose the same amount of retrieval demands on the processing system. However, these participants' performances in the Agreement condition show that, for them, Task 2 was harder than Task 1. Hence, if the two tasks had been equally hard, at least RP3's, EP1's and EP6's TR performance would have been significantly better in Task 2 than in Task 1. RP3, EP1 and EP6, therefore, appear to have had selective deficits in TR-related encoding processes (and not in TR-related retrieval processes). It is uncertain whether GP2's and EP4's TR performance would have been higher in Task 2 than in Task 1 if the two tasks had been equally hard, because they performed better on the TR condition of Task 1 than of Task 2 (albeit the between-task difference in TR performance was not significant). We cannot rule out, therefore, that GP2 and EP4 had either a selective deficit in TR-related retrieval processes or a selective deficit in TR-related encoding processes.

At this point one would wonder if we should reconsider our original claim that RP2, RP8, EP2 and EP3 had selective deficits in TR-related retrieval processes, as they performed comparably poorly in the TR conditions of Task 1 and Task 2. At least for RP2, RP8 and EP3, the answer to this question is negative, as these PWAs performed comparably poorly on Task 1 and Task 2 in both the TR and subject-verb Agreement conditions, suggesting that they had selective deficits in both TR-related and Agreement-related retrieval processes.

Of the PWAs with clearly selective TR-related encoding deficits (i.e., GP4, RP3, IP3, IP4, IP5, IP6, EP1 and EP6), some were more impaired in past reference than in future reference (i.e., IP4 and IP6), and others were more impaired in future reference than in past reference (i.e., GP4 and RP3). Likewise, of the participants with clearly selective TR-related retrieval deficits (i.e., GP3, GP5, RP2, RP8, IP1, IP2 and EP3), one was more impaired in past reference than in future reference (i.e., IP1) and two exhibited the opposite pattern (i.e., GP5 and EP3). It appears, therefore, that the direction of dissociations between past and future reference is not related to whether the source of the impairment is a selective TR-related encoding deficit or a selective TR-related retrieval deficit. Therefore, the present study does not lend empirical support to Fyndanis et al.'s (2018a) speculation that PWAs with selective TR-related retrieval deficits might be more impaired in past reference than in future reference, and PWAs with selective TR-related encoding deficits might be more impaired in future reference than in past reference.

Concluding, we provided cross-linguistic evidence that the experimental design proposed here permits teasing apart selective TR-related encoding deficits and selective TR-related retrieval deficits. This design is clinically relevant as it enables a more precise psycholinguistic assessment regarding the ability of PWAs to produce TR, and helps the clinician identify the specific source of the TR production impairment for each PWA. Future translational research should focus on developing treatment programs that would target selective TR-related encoding deficits or TR-related retrieval deficits.

Limitations of the study

In all four languages represented in the present study, the healthy control participants outperformed the PWAs, and between-task dissociations emerged in several PWAs, which demonstrates that the proposed experimental design is sensitive to TR production impairments, as well as to the differential impact of TR-related encoding vs. retrieval demands and to task effects. However, the tasks included in the proposed experimental design would be more sensitive if they consisted of more items – if, for example, either condition (i.e., TR condition and subject-verb Agreement condition) included 30 or 40 instead of 20 items. Arguably, this would permit more between-task dissociations to be detected, which would presumably lead to a more accurate diagnosis regarding the locus of impairment in TR production for each PWA.

Conclusions

Although, for some participants, Task 2 was harder than Task 1, the experimental design proposed here seems to have the potential to disentangle TR-related encoding deficits from TR-related retrieval deficits. This is evidenced by the fact that the pattern of performance of some PWAs on the two tasks suggests that these participants had selective TR-related encoding deficits, whereas the pattern of performance of other PWAs points to selective TR-related retrieval deficits. Similar experimental designs could be used to tease apart encoding and retrieval processes not only for TR but also for other morphosyntactic/morphosemantic categories that have been found to be prone to impairment in aphasia and related disorders, as well as in healthy aging. Such a category, for example, is grammatical aspect (for aspect production deficits in Greek aphasia, dementia of the Alzheimer's type, multiple sclerosis, and mild cognitive impairment see Fyndanis et al., 2012, 2013, 2018b, 2020, 2022; Manouilidou et al., 2020; Nanousi et al., 2006; and Varlokosta et al., 2006, among others).

Footnotes

- ¹ As mentioned above, it has been argued that, unlike reference to the non-past, reference to the past is discourse linked (Zagona, 2003, 2013). Moreover, since reference to the future refers to possible worlds, it involves more abstract representations as compared to reference to the past.
- ² As pointed out by Fyndanis et al. (2018a, p. 826), "(i)n the production part of the TART, the participant is presented with two horizontally arranged pictures, each accompanied by the infinitival form of a verb. The experimenter initially points to the picture on the left and describes it (e.g. *For this picture, you can say the man just ate an apple*), then points to the picture on the right and starts to describe it. At some point, the experimenter interrupts the utterance and the participant is required to complete it by providing the missing verb phrase, which includes the target finite verb form [e.g. *For this picture, you can say the man just. . . (target: . . .peeled an apple)*]. The TART, therefore, tests participants' ability to 'copy and paste' the tense/time reference feature from the source sentence to the target sentence and to retrieve the corresponding verb form/inflection."
- ³ In Russian, past-tensed verbs morphologically mark number and gender, but not person.
- ⁴ As mentioned in Fyndanis et al. (2013), when the target verb form is in 2nd person—and therefore when the cue is a personal pronoun in 2nd person (*you* in English)—some participants often interpret the cue/personal pronoun *you* included in the target sentence as an invitation to speak about themselves, which leads in their producing verb forms in 1st person and singular number,

as if they conversed with the examiner. Likewise, when the target sentence includes the cue *I*, some participants often produce verb forms in 2nd person and singular number. Such errors, therefore, are conversation-type errors and not genuine agreement errors, as they result from violation of the task instructions.

5 Base infinitives are defined as infinitives without *to*.

6 EP1 showed a between-task dissociation in the Agreement condition only based on scoring method 1 (see the Scoring Criteria subsection).

Acknowledgments: This work was partly supported by the Research Council of Norway through its Centers of Excellence funding scheme (project number 223265) and FRIPRO funding scheme (project number 287745). The contribution of Olga Buivolova and Olga Dragoy was also supported by the Basic Research Program at the National Research University Higher School of Economics.

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