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<AT>Lexico-Semantic Attrition of Native Language: Evidence From Russian–Hebrew Bilinguals

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<ABS>

Native language (L1) attrition is ubiquitous in modern globalized society, but its cognitive/psycholinguistic mechanisms are poorly understood. We investigated lexico-semantic L1 attrition in L1 Russian immigrants in Israel, who predominantly use their second language (L2), Hebrew, in daily life. We included Russian monolinguals as a control group. We tested two potential causal mechanisms of attrition: L2 interference versus L1 disuse. Participants completed a fill-the-gap task in two conditions: accuracy (producing one exactly matching word) and scope (providing as many synonyms as possible). We expected L2 interference and L1 disuse to lead to the differential reduction of accuracy and scope features, respectively. Lower scores for attriters emerged in the accuracy but not in the scope condition. Moreover, attitude towards L1 influenced attriters' accuracy—but not scope—performance, with higher L1 preference predicting higher accuracy. We provide evidence for lexico-semantic attrition in adult immigrants, pointing to L2 interference as the primary cause of impaired lexical retrieval.

<KWG>Keywords bilingualism; language attrition; Russian; Hebrew; lexical retrieval

<A>Introduction

<B>Bilingualism and Attrition: An Overview

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We live in a globalized and multilingual world with an ever-growing number of people living outside of their native ethnic and linguistic environments. In this increasingly mobile and international context, many people migrate to new countries of residence. This has led to a growing necessity to learn and master a second language (L2). Indeed, existing estimates report that nowadays more than half of the entire world's population is able to hold a conversation in more than one language (Ansaldo et al., 2008).

Typically, with time spent in the new environment, L2 gradually takes over one's native language (L1) as the dominant means of communication. This new linguistic reality leads to changes in patterns of language use reflected in a language dominance shift (Grosjean, 2015). Increased proficiency in L2 leads to higher fluency and more frequent use of this language, typically accompanied by decrease in the use of L1 (Schmid & Yilmaz, 2021). This dominance shift is associated with the emergence of *native language attrition*—the gradual decline or erosion of a person's performance in their L1 related to prolonged exposure to and use of a L2 (Köpke & Schmid, 2004). As such, language attrition reflects the dynamic nature of neurocognitive mechanisms underpinning the language function (Köpke & Schmid, 2004; Schmid et al., 2023). Identified only relatively recently as a cognitive/linguistic phenomenon on its own, L1 attrition has captured the attention of various disciplines—from linguistics to social sciences, from psychology to neuroscience—thus leading to a somewhat heterogeneous conceptualization and inconsistent terminology. Indeed, the number of theoretical revisions in this research field almost exceeds the number of experimental studies, reflecting a continuing effort to efficiently define the nature of the phenomenon and its underlying mechanisms (see Gallo et al., 2021b). Moreover, existing experimental studies often show inconsistent results, particularly regarding the putative mechanisms behind L1 attrition, and its actual causes remain

poorly understood, highlighting the need for further empirical research (Gallo et al., 2021b). Addressing the cognitive mechanisms of L1 attrition in a group of bilinguals with noncognate L1 and L2 was the goal of the present study. Below, we discuss the definition and characteristics of L1 attrition in more depth, review the main theoretical frameworks, and introduce the experimental approach that we adopted to tackle this subject.

<B>Language Attrition: Definition and Characteristics

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L1 attrition is manifested as a (partial) loss of control over the native language as a result of immersion in a foreign language (Gruzdeva, 2007). As one experimental participant aptly described the status of their L1: "My Dutch is like riding a bike. You never forget it, but you get a bit wobbly" (Amerlaan, 1996). Therefore, attrition is often described as a decrease of a previously acquired language competence, which is neither pathological nor age-dependent (i.e., not resulting from neurological, psychiatric, aging-related, or other deficits) and occurs both within and across generations and individually (Köpke & Schmid, 2004; Schmid, 2008). However, some authors have argued that this should be viewed more as a form of language development, as the shift in balance between languages is a natural aspect of bilingualism rather than purely a decline in proficiency (e.g., Włosowicz, 2017).

The process of L1 attrition is gradual and typically does not lead to a complete language loss (Schmid, 2013). Furthermore, the dynamics and severity of an individual's degree of attrition are influenced by a complex constellation of variables, such as the age at the time of emigration, the length of residence in the L2-speaking environment, specific contexts where L1 and L2 are used, and speakers' emotional attitude to the L1, to name a few (Schmid & Dusseldorp, 2010). In a review of studies of L1 attrition among migrant populations, Köpke

(2007) concluded that at the root of attrition, there are several neural and cognitive mechanisms, including (a) *neuroplasticity,* tightly linked with age—young migrants in a foreign language environment lose their native language faster than older people; (b) *frequency of use*—the thresholds of activation of a given lexical or grammatical item may vary as a function of frequency of use; (c) *inhibition mechanisms*—the necessity to control interference from the dominant language, L1, may inhibit its activation; (d) *subcortical structures recruitment*—subcortical neural structures are involved in emotional and motivational aspects of language processing and may therefore influence the maintenance of L1 and/or development of L2. Thus, L1 attrition is not a purely linguistic phenomenon but likely a result of a complex interaction between linguistic, neurocognitive, and socio-cultural variables, such as cultural and national identity shift, intergenerational language transmission, emotional attitudes, and even traumatic experiences. Among these multiple interacting variables, age of L1 attrition onset, frequency of L1 use, and attitude towards L1 (Schmid, 2002; Schmid & Köpke, 2017) have been identified as the most influential ones.

<B>Lexical Access and Attrition

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L1 attrition effects have been documented at virtually all levels of linguistic competence and language use including orthography (see Bermudez-Margaretto et al., 2021, for a review), phonology (Celata & Cancila, 2010), morphosyntax (Gurel, 2008; Kasparian et al., 2017; Pelc, 2001), and lexical semantics (Kasparian & Steinhauer, 2016; Sherag et al, 2004). Notably, these effects have been documented both in production and comprehension modalities. Nonetheless, the lexical level seems to be the first and the most severely affected by L1 attrition (e.g., Gollan

et al., 2005; Ivanova & Costa, 2008). This is reflected in difficulties in lexical access, which are manifested in different ways both in experimental conditions, where performance can be precisely measured, and in everyday life, where tip-of-the-tongue (TOT) errors and bilingual code-switching occur spontaneously.

One of the most typical characteristics of bilinguals is *code-switching,* manifest as the involuntary insertion of L2 words during L1 speech production. This has been described as one of the earliest and the most evident L1 attrition phenomena, and it was hypothesized to stem from a difficulty to retrieve L1words (Yagmur et al., 1999). Lexical access attrition has been systematically observed in studies of speech production, with findings showing both decreased accuracy (e.g., De Bot & Stoessel, 2000; Olshtain & Barzilay, 1991; Schmid, 2008; Schmid & Jarvis, 2014) and increased latency, with L1 production showing more frequent and longer pauses as well as hesitations (Bergmann et al., 2015; Schmid & Jarvis, 2014; Yilmaz & Schmid, 2012). Attriters have also demonstrated higher TOT rate incidents, which reflects the difficulty to access lexical representations (Brown & McNeill, 1966; Kamp & Pélissier, 2022). Finally, L1 attrition has been associated with diminished lexical diversity (Laufer, 2003; Schmid & Jarvis, 2014; Yilmaz & Schmid, 2012). In view of this accumulating body of evidence, it is not surprising that the problem of lexical access is one of the most crucial theoretical questions in this field (Schmid & Jarvis, 2014). Indeed, at a more general theoretical level, the main hypotheses regarding the interplay between L1 and L2 have been often framed particularly in terms of lexical access (Dijkstra & van Heuven, 2002; Durlik et al., 2016; Hoshino & Thierry, 2012; Klassen et al., 2022; Lemhöfer & Dijkstra, 2004), thus making lexical processing potentially the most informative avenue to empirically examine and understand the underlying causes of L1 attrition.

To better understand the origins of attriters' lexical difficulties, it is important to first consider the basic mechanisms of lexical access. In this regard, two different measurable phenomena involved in lexical access can be discerned. The first one, *activation scope,* refers to the range of felicitous candidates with comparable meanings activated by bilingual speakers in their L1. The second one, *selection accuracy*, refers to the selection of the best matching word among the range of less optimal candidates. Importantly, these two phenomena are not mutually exclusive, and each of them may have a unique contribution to the L1 attrition process. Nevertheless, they may affect attrition in different ways.

The L2 interference approach is supported by the dual activation account (e.g., Thierry & Wu, 2007; for a review see Kroll et al., 2015 suggesting that bilinguals activate both language codes simultaneously even in those contexts where only one language is required. The long-term bilingual coactivation changes the semantic mapping of concepts through a process of language convergence (Ameel et al., 2009). In this process, the two lexicons become interconnected, which is evidenced in semantic similarity studies showing that pairs of words with a shared translation in one language are rated as more similar in meaning than different-translation pairs (Degani et al., 2011). Moreover, both behavioral and electrophysiological (e.g., N400) findings show that bilinguals process pairs of related and unrelated words more similarly than monolinguals, indicating that bilingual experience affects semantic associations (Ning et al., 2020).

As the semantic mapping of categories in the two languages does not fully overlap, cross-language activations might result in activating lexical entries that are not precisely related to the context and to the selection of an inaccurate word. For example, a shared translation in one language (e.g., Hebrew *kli* is used both for such work tools as hammers and screwdrivers and for

kitchenware like plates and cups, whereas in English different words are used to denote these groups of objects) may lead to an inaccurate selection of a word in the other language (e.g., using the word *tool* in the context of plates and cups). However, increased inhibitory control aimed at suppressing the activation of nontarget competing representations has been argued to help the bilingual speaker to adhere to the target language and reduce competition from the nontarget one (Costa et al., 1999; Costa et al., 2008; Green, 1998; Guo et al., 2011; Kroll et al., 2008). Thus, the interference account entails two partially overlapping subcomponents: (a) a parallel and automatic activation of L2 and L1 lexicons in bilinguals, which entails direct interference between them, and (b) inhibition of the nontarget language to reduce lexical competition between languages. We refer to this framework as the L2 interference hypothesis.

In turn, the L1 disuse approach is supported by the frequency lag hypothesis account (Gollan et al., 2011; see also the weaker links hypothesis, Gollan et al., 2008), whereby bilinguals are presumed to use L1 words less often than their monolingual peers, as they need to divide their language use between two languages. This reduction should lead to a reduced accessibility of specific lexical items due to the comparatively lower activation status and/or weakened links between lexical representations. Therefore, the necessity to use two languages may lead to general detrimental consequences for lexical processing associated with both L1 and L2 use due to relatively reduced use of words in both languages. These consequences would be more salient for the less used language, that is, L1 in attriters. We refer to this framework as the L1 disuse hypothesis.

The frequency lag hypothesis received support from studies using single word production tasks (e.g., Gollan et al., 2011; Ivanova & Costa, 2008), TOT methodology (e.g., Gollan & Acenas, 2004; Gollan & Silverberg, 2001; Li et al., 2017), and memory recognition tasks

(Mizrahi et al., 2021). These studies showed that bilingual speakers take longer to name pictures in L1, demonstrate higher TOT rates, and have a reduced semantic and phonetic fluency, compared to monolingual speakers (Gollan et al., 2008; Goldrick & Gollan, 2023; see also Blanco-Elorrieta & Caramazza, 2021; Sadat et al., 2016, for more evidence of competition from the nontarget language). Although these results in principle can be explained both by the L1 disuse and L1–L2 interference mechanisms, arguably the strongest source of evidence for the L1 disuse account has come from studies involving adopted children that show an extremely fast, almost absolute, and practically irreversible attrition after early L1 disruption (Isurin, 2000; Nicoladis & Grabois, 2002; Pallier et al., 2003; Ventureyra et al., 2004). Other studies, on the contrary, have provided evidence for the transfer of L2 structures into L1 processing at different levels, such as phonology (De Leeuw et al., 2018) and syntax (Dussias, 2004), thus supporting the L2 interference account. In view of the inconclusive data, Kreiner and Degani (2015) proposed an integrated account, which incorporates both mechanisms and assumes that they operate on different timescales. One mechanism adjusts the strength of connections between lexical units on the basis of their accumulated frequency of use, and the other one adjusts the activation balance between the different languages in real time and is more sensitive to contextual variables, such as the task demands and the target language.

Although both mechanisms seem to affect bilingual speakers' performance, the question of their relative contribution to attrition has been only scarcely investigated (Isurin, 2005; Köpke, 1999; Schoenmakers-Klein Gunnewiek, 1998). To the best of our knowledge, the only two studies that focused directly on the issue of lexical L1 attrition from the viewpoint of the two theoretical accounts above provided contradictory evidence. The first study examined Turkish and Moroccan attriters in the Netherlands (Schmid & Yilmaz, 2021), using a picture naming task

to compare L1 attrition in these two populations of late L2 speakers of Dutch. One group (Turkish migrants) was largely monolingual before moving to the Netherlands, and the other group included native Moroccan speakers with a multilingual background. To the extent that the interference mechanism contributes to attrition, stronger interference was expected in the multilingual Moroccan sample than in the Turkish one. This should be the case because multilingual speakers experience competition from more languages. At the same time, both samples were predicted to be similarly affected by the disuse mechanism because both groups experienced a similar level of L1 disuse. The results indicated that attrition effects were indeed stronger in the Moroccan than in the Turkish sample, with no effect of L1 exposure frequency, suggesting that the resulting lexical attrition was largely due to L2 interference.

A more recent study that examined L1 attrition among Russian attriters in Israel (Baladzhaeva, 2021) compared Russian–Hebrew bilinguals and Russian–English–Hebrew trilinguals through a variety of tasks. The tasks assessed cognitive mechanisms linked with priming of low-frequency words, perceived word similarity, and object categorization. The main findings did not support either of the theoretical mechanisms discussed above. On the one hand, exposure to L1 following emigration did not exert any influence on attrition intensity, thus failing to confirm the disuse account. On the other hand, trilinguals did not show stronger L1 attrition than bilinguals (in contrast with Schmid & Yilmaz's, 2021, results), which seemingly refutes the purely interference-based mechanism. In sum, the lack of consisting evidence and the overall scarcity of studies examining the mechanisms underlying lexical attrition along with their inconclusive findings call for further research.

<A>The Present Study

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The present study aimed to investigate L1 lexical access in attriters by examining directly two phenomena involved in lexical access: activation scope and selection accuracy. To this end, we used a written sentence completion task with two different tasks. In one task, participants were required to select the most suitable word to complete the sentence; hence their performance allowed us to examine their selection accuracy. In the other task, they were required to produce as many suitable words to complete the sentence as they could; hence their responses allowed us to examine their activation scope. Importantly, the two potential mechanisms of attrition—L1 disuse and L2 interference—were expected to affect the activation scope and the selection accuracy in different ways.

According to the L2 interference hypothesis, as L2 proficiency and use increase, its semantic mapping and spreading activation clusters become more dominant. This mechanism is expected to affect the selection accuracy due to a stronger crosslinguistic interference exerted by L2 on L1 (e.g., Berghoff & Bylund, 2023). However, this mechanism is not expected to necessarily reduce activation scope; in fact, due to the dual language activation, it might even increase the activation scope by activating inaccurate lexical entries via words in L2 with a shared translation.

On the other hand, according to the L1 disuse hypothesis, attrition would be a result of the shift in the frequency of use of one language compared to the other one, entailing generally reduced proficiency in the less frequently used language (e.g., Mytara & Köpke, 2024; Schmid & Jarvis, 2014). In the case of L1 attrition, this would weaken the connections between lexical representations, resulting in reduced spreading of activation within the lexical semantic networks. Hence, a relatively smaller number of L1 entries associated with the context would be accessible for activation. This would be reflected in a smaller scope of potential responses for

attriters as compared to nonattriter controls. Note that the limited activation may harm the speaker's ability to select the most accurate word, but such accuracy impairment will be dependent upon and correlated with the decrease in the activation scope (i.e., impaired accuracy in the absence of reduced scope is not expected according to the disuse hypothesis). Finally, since the two mechanisms are not necessarily mutually exclusive, their concurrent involvement would be reflected in the impairment of both scope and accuracy features of lexical access.

There are various observations in the literature supportive of such dissociated predictions. First, a dysfunction at the lexical level, caused by language impairments such as aphasia (or similarly, by the disuse of a lexicon), typically results in a failure to activate and subsequently produce the target, thus resulting in nonresponses or circumlocution (low number of outcomes, i.e., lower scope) rather than in semantic or phonological production errors (low accuracy; Caramazza et al., 1986; Vitevitch, 2002). Moreover, the frequency of use has been shown as one of the most determinant variables for lexical access of target words both in healthy controls and in anomic patients, whose main lexical impairment is reflected precisely in a large number of nonresponses rather than in production errors (e.g., Barry et al., 1997, Cuetos et al., 1999, Ellis & Morrison, 1998). In this sense, words with lower frequency of use have a lower probability of being accessed (i.e., low scope) rather than a higher probability to manifest production errors (i.e., low accuracy). To support this, several studies have shown that vocabulary recall is affected by the degree of the corresponding language disuse (Bahrick, 1984). Consequently, when individuals attempt to use a disused language, lexeme information from the more frequently used language may inadvertently slip in. This interference occurs because the more practiced language's entries are more readily accessible and less inhibited.

In line with this, traditional computational models of impaired lexical access in speech production (e.g., Foygel & Dell, 2000), successfully verified through differential outcomes of aphasic patients and healthy controls, have stated that errors might occur at either lexical selection or phonological encoding stages, when another, related unit is more activated than the target one, causing the incorrect selection of such a nontarget candidate (which also supports the L2 interference hypothesis). Following this reasoning, lower accuracy would result from the activation of other candidates (either in L1 or in L2) rather than being a product of a mere nonactivation of the target as a consequence of language disuse.

The present study aimed to fill the gap in the L1 attrition literature on the basis of these premises. Here, for the first time to our knowledge, we compared L1 lexical access performance of L1 attriters and nonattriter controls in both scope and accuracy tasks in a study directly aimed at assessing both L1 disuse and L2 interference as the two (main) causal mechanisms of L1 lexical-semantic attrition. Although, as discussed above, disentangling the two mechanisms completely may be challenging, given their close interrelationship, simultaneous inclusion of these two components is necessary to attempt an investigation of their distinct and possibly combined contributions to the L1 attrition phenomenon. To this end, we collected a sample comprising a group of L1 Russian–L2 Hebrew speakers living in Israel (attriter group) and a group of L1 Russian speakers living in Russia (control group). Scope and accuracy features of lexical access were assessed in two fill-the-gap production tasks: One that requires participants to provide as many candidate words as possible (scope condition) and the other one requiring them to produce the best matching item (accuracy condition). We predicted that if L1 disuse is the dominant mechanism behind L1 attrition, then attriters, compared to controls, would show lower scope in their L1 lexical access. In contrast, impaired accuracy in attriters could be

expected in case of an L2 interference involvement. Significant group differences in both scope and accuracy features could be expected in case of the concurrent involvement of both mechanisms.

<A>Materials and Methods

<B>Participants

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We collected data from two groups of participants. The attriter group consisted of 195 participants (149 females, age 42 ± 10.4 years) whose native language was Russian and who had been living in Israel for an extended time (average residency = 20.5 ± 9.9 years) and spoke Hebrew in their everyday life. According to participants' self-reports, the general level of L2 proficiency was 5.2 out of 6 (on average). Their level of education was the following: 8.2% high school, 48.7% graduate, 42.6% postgraduate.

The nonattriter group consisted of 112 Russian native speakers (77 females, age 26 ± 9.1 years) living in Russia, none of whom spoke Hebrew, according to their self-reports. Participants both in the attriter and control groups reported at least some knowledge of other nonnative languages, including English, German, Polish, French, Irish, Spanish, Italian, Mandarin, Arabic, Kazakh, Ukrainian, Swedish, Tatar, Armenian, Estonian, Japanese, Lithuanian, Malay, Czech, Portuguese, Georgian, Finnish, Hungarian, and Mongolian. The average number of languages known to some extent by attriters was 4.28, *SD* = 1.39, range: 2–11. The average number of languages known to some extent by controls was 2.8, *SD* = 1.03, range: 1–6. Unfortunately, no data are available regarding the exposure to, age of acquisition of, and proficiency in these nonnative languages. Although we recognize that this is not ideal since the interference of other

languages could come not only from Hebrew, but from these other languages as well (see, e.g., Schmid & Yilmaz, 2021), the reader has to consider that in our current globalized world, it is almost impossible to find pure monolinguals. Moreover, we believe that the very low variability of the control group in these regards is unlikely to influence the results.

The nonattriters' level of education attainment was the following: 58.9% high school, 35.7% graduate, 3.6% postgraduate. The groups could not be fully matched on age, education, and gender. Importantly, age and education are known to influence vocabulary breadth (e.g., Agustin-Llach & Canga Alonso, 2016). Therefore, in principle, the Russian–Hebrew bilinguals, who are older and more highly educated than their monolingual control-group peers, could have higher vocabulary scores. However, this difference between the two groups does not predict specific task performance hypotheses put forward in our study. More importantly, we controlled for the effects of these variables in all of our statistical analyses (see below). The study was approved by the Higher School of Economics University Ethics Committee and complied with the Declaration of Helsinki on ethics principles.

<B>Materials

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For the purposes of this study, we developed the stimuli on the basis of the Russian Sentence Corpus, normed previously (Laurinavichyute et al., 2019). One hundred sentences were created (see below for an example and the full list in Appendix S1 in the online Supporting Information). Four versions were generated for each sentence—two versions were created for the accuracy task and two for the scope task. For each task, in one version, a verb was missing, and in the other, a noun was missing. Each sentence was presented with a single blank. Russian exhibits a rich lexical diversity, particularly within the noun and verb categories (Lyashevskaya, 2013), making

them ideal for investigating the scope and accuracy of lexical access. The diversity of these categories also mirrors the intricacies of real-world language use, thereby enhancing the ecological validity of our study. The lexical diversity of nouns and verbs was particularly beneficial for the scope task (both tasks are described below in more detail). At the same time, their use in the accuracy task enabled us to maintain participants' responses within the framework of specific collocations, an outcome that would not have been achievable through the use of adjectives or adverbs. For instance, in the construction *питьевая вода* ("drinking/potable water"), the noun *вода* ("water") serves a crucial, nonsubstitutable role, whereas the adjective *питьевая* ("drinking") can be replaced by a variety of adjectives with the potential to substantially alter the overall meaning of the sentence. The blanks were distributed in such a way that they were equally likely to be nouns or verbs.

In the scope task, participants had to type in as many plausible synonyms as they could think of (up to a maximum of 10) to fill in the omitted word. For instance, in the sentence *Необходимо было срочно пополнить запасы питьевой воды, так как наши ___ были пусты и прогноз погоды обещал, что дождь будет не скоро* ("It was necessary to replenish the supply of drinking water, since our ___ were empty, and the weather forecast promised that it would not rain any time soon"), the original word *канистры* ("canisters") was blanked out, which could be replaced with synonyms such as *контейнеры* ("containers"), *бутылки* ("bottles"), *баки* ("tanks"), *фляги* ("flasks"), and others. Participants were instructed to provide as many candidate answers as possible.

In the accuracy task, participants performed a similar task, except this time the sentences were designed in such a way that the blanked-out word had a single felicitous candidate as per the sentence context (see details in the Procedure section). For this purpose, we selected words

on the basis of a high frequency of collocation (i.e., appearing together) with the neighboring words. Stable collocations were chosen on the basis of the mutual frequency of the key term and its collocate (Russian National Corpus, https://ruscorpora.ru/). For instance, in the same sentence *Необходимо было срочно пополнить запасы питьевой ___, так как наши канистры были пусты и прогноз погоды обещал, что дождь будет не скоро (*"It was necessary to replenish the supply of drinking ___, since our canisters were empty, and the weather forecast promised that it would not rain any time soon"), the blanked out word was the noun *вода* ("water"), which is the only suitable candidate to fill the gap. Participants were instructed to provide a single best-matching answer to fill the blank.

These stimuli were used to create a questionnaire with four sentence lists using Qualtrics online software. Each list included all 100 sentences (50 for accuracy, 50 for scope), such that each sentence appeared in each list in only one of the four possible versions (verb–scope, verb–accuracy, noun–scope, noun–accuracy), using a Latin square design for counterbalancing. Thus, each sentence was presented only once to each individual participant, to avoid confounding the results by learning the specific sentences' content.

<B>Procedure

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The study was advertised on social media (using groups on the VK social media platform for nonattriters and Facebook groups of Russian-speaking immigrants in Israel) by providing a link for participants to access the study. The online survey consisted of two sections. The first section included questions assessing demographic and language background information. The questions for both nonattriters and attriters covered age, gender, education level, and additional languages spoken. In the case of attrition, additional questions were related to length of residency in Israel,

level of proficiency in Hebrew/Russian before and after moving to Israel, and partner's native language, among others. (see Appendix S2 in the online Supporting Information for the full list of questions). These questions were created in such a way that each question could be transformed into a scale reflecting the participant's level of adherence to Russian or Hebrew. For instance, the question "How often do you communicate with friends and relatives from Russian-speaking countries?" could be assessed on a 5-point scale reflecting the degree of exposure/attachment to L1 using graded answer options *very rarely / rarely / sometimes / often / always* (subsequently transformed to numerical scores 1 to 5, respectively). This first section of the survey for attriters produced 18 scales for L2 and 18 scales for L1 adapted from the Language Experience and Proficiency questionnaire (Marian et al., 2007; see Appendix S2 in the online Supporting Information), allowing us to rank participants on the basis of general scores for L1 and L2 parameters.

The second part of the survey was the main experimental section with 100 one-sentence trials, identical for both samples. Participants were randomly assigned to one of the four lists, with four conditions randomized according to a Latin square design. Thus, the first condition that a participant could be presented with was either verb–scope, verb–accuracy, noun–scope, or noun–accuracy. Participants were instructed to enter as many words as they could think of in the scope task and to enter the single word that best matched the context in the accuracy task. Sentences were presented one at a time in the center of the screen, with one of the words missing. In the scope condition, there were 10 empty boxes provided for entering synonyms below the sentence. In the accuracy task, only one empty box was provided. The task was to type in the answer in the empty field(s). After providing their response(s), participants clicked the "Next" button and proceeded to the next trial. There was no time limit to complete individual

trials and/or the entire study. Self-paced breaks were included every 25 trials. Participants were allowed to shut down the survey at any moment. Prior to the study, participants were informed that those who completed the survey would receive a $10 Amazon gift voucher.

Participants' responses were examined by four native Russian speakers, who decided whether they were correct or incorrect. For the accuracy task, the scores were binary (1 = *correct*; 0 = *incorrect*), whereas for the scope task, the score per each sentence ranged from 0 to 10, representing the actual number of plausible synonyms produced by the participant.

<B>Statistical Analysis

<C>*Group Comparisons*

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To test for the emergence of L1 attrition in our sample, we compared the performance of the attriter and control groups by means of repeated-measures mixed-effects regression statistics based on single-trial data. For the scope task, we examined by-trial differences by fitting a linear mixed-effects regression model with single-trial scope performance (ranging between 0–10) as the dependent variable (DV), group as the independent variable (IV), age, gender, and education as covariates, random effects for individual intercepts and random slopes for single trials. For the accuracy task, a logistic mixed-effects regression with the same model structure and single-trial accuracy (correct/incorrect) as the DV was employed. In the attriter group, only 0.2% of the total responses were nonresponses, and there were no instances of nonresponses in the control group.

<C>*Analyses for Attriter Subsample*

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After testing for the presence of L1 attrition, we proceeded to test how interindividual differences in the linguistic experience of attriters modulate its emergence. With the aim of subsuming questionnaire items in grouping latent variables, we performed confirmatory factor analysis (CFA) in the framework of structural equation modeling (SEM) in the attriter group. We first discarded questionnaire items with more than 20% of missing data (i.e., "How often do you use Hebrew with pets?") as well as those showing little variability, with almost the totality of the responses falling into one category (i.e., "How often do you use Russian in clubs?", "How often do you listen to the radio in Russian?"). Subsequently, we designed three SEM models to perform CFA on three latent factors, namely (a) exposure to L1, (b) exposure to L2, and (c) attitude towards L1/L2. This procedure allowed us to extract the minimum number of individual variables (i.e., latent factors), which subsume all shared variance from related questions in the questionnaire. In other words, our goal was to obtain a measure of each of the three variables that underlie answers to our questionnaire but cannot be directly observed. The rationale behind individuating these three precise factors is that they are commonly argued as the principal cause of L1 attrition in the literature (see Gallo et al., 2021b, for a review). We used maximum likelihood with missing values procedure to estimate the model. Model fit was assessed using the comparative fit index, the Tucker-Lewis index, and the root-mean-square error of approximation. Omitted paths with a potential to increase goodness of fit were explored and added using modification indices. All models' fit to data was satisfactory. Predicted values of the latent variables were extracted through an automatized procedure using STATA 15 software (StataCorp., 2017, Version 15). Interfactor correlations were as follows: exposure to L1 versus exposure to L2 $r = .165$; exposure to L1 versus attitude towards L1/L2 $r = -.405$; exposure to L2 versus attitude towards L1/L2 $r = -.396$.

Next, we performed linear mixed-effects analyses to test whether the latent factors could predict scope and accuracy performance, but no significant effects emerged. Since SEM relies on a priori theoretical assumptions to define model structure and investigate latent factors (see, e.g., Di Franco, 2013; Maxwell, 1977), it must be noted that previous L1 attrition literature, although clearly individuating L1 exposure, L2 exposure, and attitudes towards L1/L2 as the main putative causal variables for L1 attrition, shows little agreement on how to measure such variables (see, e.g., Gallo et al., 2021b, for a review). Hence, although our SEMs displayed satisfactory fit to data, they might have lacked precision in individuating such latent factors, thereby failing to grasp their predictive power on attriters' performance. Given these considerations and the exploratory nature of this study, we decided to proceed by adopting an exploratory approach and selected specific questionnaire items as proxy variables for each of the three latent factors (i.e., exposure to L1, exposure to L2, and attitude towards L1/L2). The three proxies were chosen by individuating the variable with the highest factor loading in the relative SEM. The specific questionnaire items were "How often do you communicate with friends and relatives from Russian-speaking countries?" for L1 exposure (hereafter, L1 exposure proxy), "How long have you resided in Israel?" for L2 exposure (hereafter, L2 exposure proxy), and "Is it more convenient for you to speak Russian or Hebrew?" for attitude towards L1/L2 (hereafter, attitude proxy). Next, we performed linear mixed-effects analyses, fitting a mixed-effects linear regression model with single-trial scope and a mixed-effects logistic regression with single-trial accuracy as the DVs. For both regressions, the IVs were the three proxy variables alongside the participants' age, gender, and education as covariates. We also included random effects for individual intercepts and by-trial slopes.

<A>Results

<TXT>

Below, we summarize the main results of the present study. For the sake of clarity, we focus here on statistically significant findings from the main a priori defined comparisons; full results are presented in Tables 1–4.

For the accuracy task, group comparisons detected differences between attriter and control groups at single-trial level: Namely, the logistic mixed-effects regression revealed that attriters had a 30% lower probability of choosing the correct word to fill the gap in the accuracy task than the controls, odds ratio = 0.7, $p < .001$; see Figure 1. The education and age covariates also showed significant main effects, indicating that they also play a role in accuracy performance. Nonetheless, having controlled for these potential confounders, we could safely attribute the observed group effect to our variable of interest, that is, group as IV. Importantly, no between-group differences emerged for the scope task, $b = –0.15$, $p = .373$. For both accuracy and scope models, as a sensitivity analysis, we tested the model by adding the number of languages spoken by participants as a covariate. In both cases, the pattern of significance did not change. Full model estimates are reported in Tables 1 and 2.

<COMP: Place Figure 1 near here>

<COMP: Place Table 1 near here>

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Follow-up analyses conducted in the attriter subsample revealed a significant main effect on accuracy score of attitude proxy. In particular (see Figure 2), as compared to participants who expressed a preference towards L2, those with no particular preference showed a 58% higher probability of selecting the correct word, odds ratio = 1.58; $p = .002$, and the probability was

77% higher for those who reported L1 preference, odds ratio = 1.77; $p < .001$. A significant main effect of education also emerged in this subsample, confirming the result observed in the group comparisons. Notably, none of the proxies significantly predicted the scope performance in this group. See Tables 3 and 4 for full model estimates.

<COMP: Place Figure 2 near here>

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<COMP: Place Table 4 near here>

<A>Discussion

<TXT>

The present study used two novel tasks in order to examine the putative mechanisms responsible for L1 attrition at the level of lexical semantics. Comparing the performance of L1 attriters and nonattriter controls on both the scope and accuracy of sentence completion in L1 allowed us to test the two theoretical accounts positing different causal mechanisms of lexical L1 attrition, namely the dual activation hypothesis and the frequency lag hypothesis. Whereas the dual activation hypothesis suggests L2 interference as the main driver of L1 attrition, the frequency lag hypothesis stresses L1 disuse as the main causal mechanism. We hypothesized that if L2 interference drives the lexico-semantic attrition of L1, as proposed by the dual activation hypothesis, then it should be reflected in a lower accuracy when activating the lexical candidate in the accuracy task. On the other hand, if it is the L1 disuse that makes a decisive contribution to L1 lexico-semantic attrition, as argued by the frequency lag hypothesis, then attriters would demonstrate a narrower scope of lexical semantic activation than nonattriter controls. If both mechanisms are at play, then group differences should be observed in both tasks.

Our results clearly indicate a significantly lower performance in attriters than controls in selecting the single correct candidate in the accuracy task, whereas no reliable group differences were observed in the scope task. Moreover, only accuracy but not scope performance was significantly moderated by attriters' attitudes to L1/L2, with higher accuracy exhibited by those favoring L1 or having no language preference over those preferring L2. Therefore, our data indicate that a putative L2 interference mechanism seems to exert a more determinant influence on L1 attriters' lexico-semantic performance than L1 disuse.

Our results are in line with one of the only two studies that approached the issue of disentangling between the (partially) competing causal mechanisms of lexical attrition. One such study is by Schmid and Yilmaz (2021); the other such study, Baladzhaeva (2021), did not produce a conclusive result that could lend unequivocal support to either of the two accounts (see Introduction). As mentioned in the introduction, Schmid and Yilmaz (2021) compared L1 lexical attrition using a picture-naming task in two populations of late learners of L2 Dutch: Those who were largely monolingual before moving to the Netherlands and those who already had a multilingual background prior to emigrating. Although both samples could be similarly affected by L1 disuse, the multilinguals were expected to experience significantly stronger interference from languages other than L1. Indeed, stronger L1 attrition effects emerged in the multilingual sample, with no effect of L1 exposure frequency, suggesting that the lexical attrition was largely due to higher level of interference of other languages. Thus, both Schmid and Yilmaz's (2021) and our investigation appear to support the dual activation hypothesis over the frequency lag hypothesis.

The dual activation hypothesis aligns well with the current understanding of bilingual neurocognitive mechanisms, with a large body of findings supporting the simultaneity and

nonselective activation of both languages in the bilingual brain (see, e.g., the bilingual interactive activation plus model, Dijkstra & Van Heuven, 1998, 2002). Indeed, it is important to note that attriters and bilinguals are not separate epistemological entities, but rather, one is a particular case of the other: Namely, all attriters are first and foremost bilinguals. This view is becoming widely accepted, and it is supported by many researchers in the field of bilingualism and attrition (e.g., Gallo et al., 2021a; Schmid & Köpke, 2017). Since the dynamic interaction between the two languages (i.e., crosslinguistic interference/interplay/interaction) is commonly accepted as the most defining feature of bilingualism (see Kroll et al., 2012, 2015) and attrition is a particular case of bilingualism, it is logical to expect a causal role of crosslinguistic interplay in L1 attrition as well.

In support of this view, several previous studies have demonstrated how bilinguals' L1 and L2 interact with and affect each other (Bermudez-Margaretto et al., 2022; Coderre, 2015; Kroll et al., 2012). Besides the naturally presumed effects of the native L1 on a subsequently learned and frequently less proficient L2, considerable evidence is also available for the effects of L2 on L1. Even in contexts where only L1 is used, bilinguals show various consequences of L2 interference, such as lower accuracy and speed of word production and increased error rate (e.g., TOT occurrence) in L1 (Bialystok et al., 2012; Costa & Sebastián-Gallés, 2014; Kroll et al., 2015). Neurophysiological evidence points in the same direction: For instance, Kasparian and Steinhauer (2016) observed larger P600 event-related brain potential for attriters as compared to monolingual controls in an acceptability judgment task. Since P600 is usually linked to top-down controlled processes of resolving ambiguities, reanalysis and repair of linguistic input (Contier et al., 2022; Ovans et al., 2022), this result was attributed to an increased conflict monitoring in attriters while processing lexical semantic anomalies. This increased reliance by bilinguals on

conflict monitoring to manage two competing linguistic systems is widely demonstrated (see Bialystok, 2017), and, furthermore, is thought to have positive implications for general cognition and cognitive aging (see Gallo et al., 2022). This observation can also be useful for interpreting our present results. Indeed, the lower accuracy scores displayed by attriters could (in addition to our explanation above) reflect their reduced monitoring efficiency. As L1 attrition progresses, attriters effectively become more similar to monolinguals than bilinguals and may, as a result, show a decline of monitoring abilities, subsumed under the mechanisms pertaining to selection accuracy. This suggestion is of course still tentative and further, more focused research is needed to explore and verify it.

Finally, attitude towards L1 influenced attriters' performance only in the accuracy task but not in the scope task. Individual attitudes towards L1/L2 have been shown to affect the degree of attrition (Ben-Rafael & Schmid, 2007; Cherciov, 2013; Schmid, 2002), which corroborates the present result to an extent. One noteworthy example is an investigation of L1 attrition in German Jewish citizens who fled to English-speaking countries during World War II (Schmid, 2002). In this investigation, the negative emotional attitude towards the native German language, which became "the language of the persecutor," was the single most powerful predictor of the degree of L1 attrition. The present data add a specific aspect to this phenomenon, namely, attitude toward L1, which turned out to be a powerful predictor of L1 attrition, observed only in the accuracy but not in the scope task. This result reinforces the view that L2 interference (not only at the lexical but also at affective level) might be the driving force underlying L1 attrition.

One limitation of the present study pertains to the lack of detailed information regarding the educational background of the Russian–Hebrew bilinguals in their native language, Russian.

On average, our attriter participants emigrated to Israel at the age of 21.5, that is, after completing their high school in Russian (typically at the age of 17), matching the nonattriter group in that respect. However, although we collected data on the overall educational level of participants, the exact extent of their education in L1 remained unknown at the individual subject level. Such data could provide deeper insights into the linguistic experiences of bilingual participants and their potential L1 attrition. Future studies should consider including this aspect to elucidate any potential relationships between education in L1 and L2 and language attrition phenomena. Another potential limitation arises from the sequence of our survey presentation. By presenting (as is customary in such studies) demographic questions prior to the experimental task, we cannot rule out the possibility that attention drawn to these demographic details might have indirectly influenced participants' responses to the main task. Future studies could mitigate this possibility by positioning the majority of demographic queries after the main experimental task to minimize such potential biases.

To sum up, the present study provides new empirical data that contributes to understanding the causal mechanisms of L1 attrition. Our findings consistently point towards the primary role of L2 interference over L1 disuse in the deterioration of L1 lexical-semantic processing in attriters, with the additional variable of attitudinal bias towards the preferred language. These findings are in line with current theories and recent cognitive and neurophysiological findings pointing to the simultaneous L1–L2 activation in bilinguals. Future attrition research might consider extending these results with the help of time-resolved neuroimaging methods able to measure lexico-semantic activation at the brain level, to provide further and more robust evidence for the role of L2 interference as a causal mechanism of

attrition as well as to replicate in a more controlled laboratory settings the present findings, which were collected using on-line research methods.

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<A>Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Stimuli.

Appendix S2: Socio-Demographic and Language Background Questionnaire.

Appendix S3: List of Items Informing the Three Structural Equation Modeling Latent Variables.

Tables

Table 1 Estimates from the mixed-linear regression predicting single trial scope on the basis of group (controls vs. attriters)

Variables	Model estimates		
	b	*p*	[95% CI]
Group			
Controls		Referent	
Attriters	–0.15	.373	[–0.505, 0.19]
Age	–0.002	.72	[–0.014, 0.01]
Gender			
Female		Referent	
Male	0.15	.271	[–0.117, 0.417]
Education	0.09	.124	[–0.023, 0.194]

Table 2 Estimates from the mixed-logistic regression predicting single trial accuracy on the basis of group (controls vs. attriters)

Variables	Model estimates		
	Odds ratio	*p*	[95% CI]
Group			
Controls		Referent	
Attriters	0.7	<.001	[0.575, 0.843]
Age	1.01	<.001	[1.005, 1.019]
Gender			
Female		Referent	
Male	0.89	.133	[0.771, 1.035]
Education	1.1	.002	[1.037, 1.171]

Table 3 Estimates from the mixed-linear regression predicting single trial scope on the basis of L1 attrition proxies (attriters only)

Variables	Model estimates		
	b	*p*	[95% CI]
L1 exposure proxy			
Rarely		Referent	
Several times per year	–0.2	.559	[–0.867, 0.469]
Monthly	–0.02	.957	[–0.6, 0.568]
Weekly	0.18	.487	[–0.328, 0.688]
Daily	0.3	.324	[–0.295, 0.895]
Attitude proxy			
L1 < L2		Referent	
L1 = L2	0.24	.46	[–0.399, 0.882]
L1 > L2	0.16	.653	[–0.529, 0.844]
L2 exposure proxy	–0.003	.802	[–0.027, 0.021]
Age	0.003	.745	[–0.017, 0.024]
Gender			
Male		Referent	
Female	0.28	.157	[–0.109, 0.675]
Education	0.02	.811	[–0.135, 0.172]

Note. L1 = native language; L2 = second language.

Table 4 Estimates from the mixed-logistic regression predicting single trial accuracy on the basis of L1 attrition proxies (attriters only)

Variables	Model estimates		
	Odds ratio	*p*	[95% CI]
L1 exposure proxy			
Rarely		Referent	
Several times per year	0.95	.767	[0.688, 1.317]
Monthly	0.98	.867	[0.733, 1.299]
Weekly	1.04	.767	[0.808, 1.336]
Daily	0.96	.774	[0.717, 1.28]
Attitude proxy			
L1 < L2		Referent	
L1 = L2	1.58	.002	[1.179, 2.118]
L1 > L2	1.77	<.001	[1.289, 2.441]
L2 exposure proxy	0.99	.557	[0.985, 1.008]
Age	1.01	.065	[0.999, 1.02]
Gender			
Male		Referent	
Female	0.89	.247	[0.737, 1.082]
Education	1.11	.006	[1.031, 1.198]

Note. L1 = native language; L2 = second language.

Figures

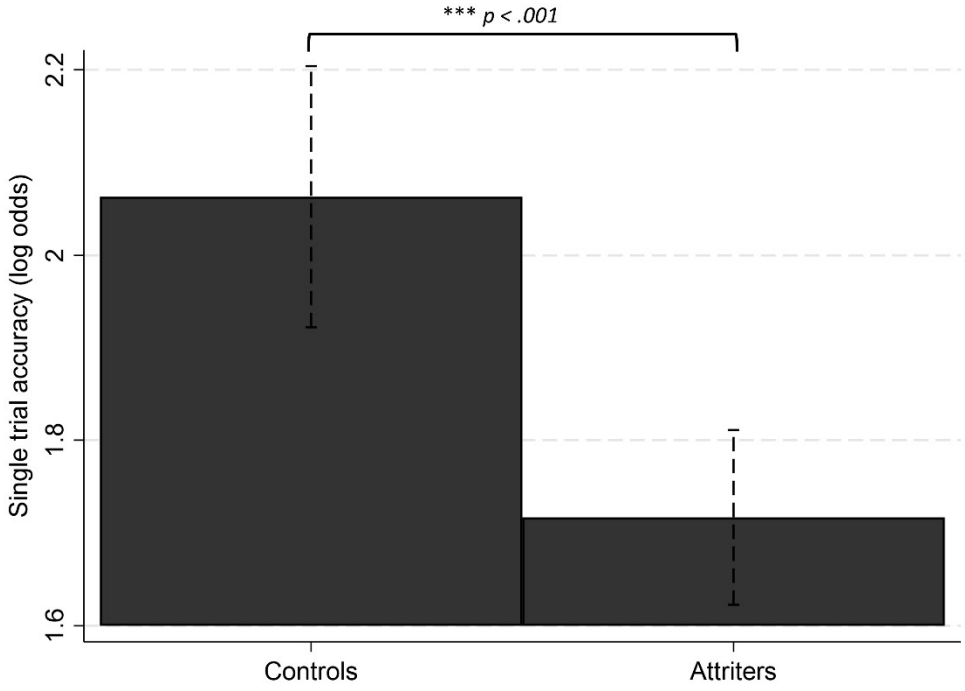

Figure 1 Group differences in log odds of single trial accuracy.

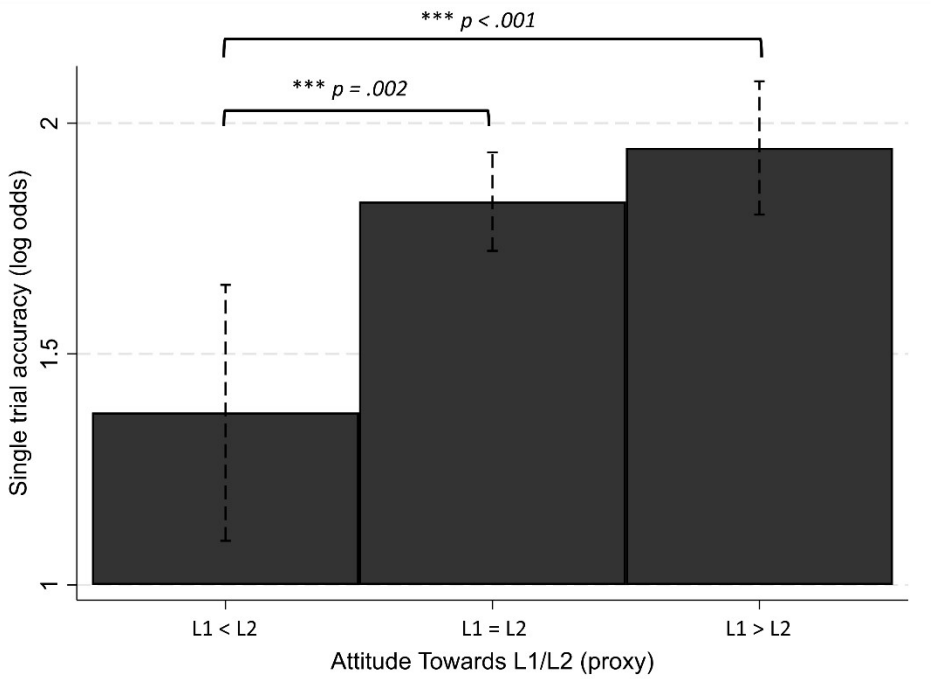

Figure 2 Predicted log odds of single trial accuracy on the basis of attitude towards L1/L2.