

# Cultural bias in heritage language processing: A web eye-tracking study of dominant Russian and endangered Juhuri

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## Research Article

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# Abstract

The present study investigates the role of cultural bias in lexical processing among Mountain Jewish multilingual immigrant speakers across Juhuri and Russian, two heritage languages (HLs) differing in dominance, status, and communicative function. Drawing on theoretical accounts of cultural congruency and lexical-conceptual associations, the study examines how culturally grounded knowledge influences both the efficiency and time course of lexical access. For each language, participants completed a visual world eye-tracking task alongside accuracy and reaction time measures across three experimental conditions: culturally congruent items, which align with the culture associated with the target language, culturally comparable non-congruent items, and neutral items. Results revealed a systematic asymmetry between the two languages. In Russian, the dominant HL, cultural bias effects emerged in online gaze patterns, indicating rapid and relatively automatic integration of culturally congruent information during lexical access, along with ceiling performance in accuracy and reaction times. In contrast, in Juhuri, a weaker and endangered HL, cultural effects appeared primarily in offline measures, with both culturally congruent and non-congruent items facilitating performance relative to neutral items. This pattern suggests that, in Juhuri, contextual support, rather than cultural specificity per se, plays a central role in lexical identification. These findings demonstrate that culturally grounded conceptual knowledge is available across languages but differs in the efficiency and dynamics with which it is accessed. More broadly, the results highlight how language dominance, proficiency, and sociolinguistic context jointly shape lexical processing in multilingual speakers, particularly in heritage and endangered language settings.

## Introduction

The use of two heritage languages (HL) within the same speech community is relatively rare. One such case is the community of Mountain Jewish (MJ) immigrants in Israel, who use both Russian and Juhuri, an endangered HL that has increasingly taken on the status of an ethnocultural language (Shabtaev, 2025a). This sociolinguistic configuration provides a unique opportunity to examine how cultural knowledge interacts with HL processing across languages that differ in dominance, vitality, and functional distribution. The present study thus investigates the role of cultural bias, namely the congruency between item content and the cultural context associated with a target language, in lexical processing in these two languages.

A growing body of research suggests that language processing in bilinguals is shaped not only by linguistic structure and proficiency, but also by cultural context (Liu et al., 2021; Pan et al., 2021; Zhang et al., 2013). Cultural information can influence lexical access, bias language selection, and modulate the activation of conceptual representations across languages. Such effects are understudied but particularly relevant in HL contexts, where language use is often distributed across distinct social and cultural domains, potentially strengthening the association between linguistic forms and culturally grounded knowledge.

Building on this literature, the present study examines how cultural bias influences real-time lexical processing in two HLs that differ in dominance. By combining offline measures (accuracy and reaction times) with online eye-tracking measures, the study captures both end-state outcomes and the temporal dynamics of lexical activation. This approach provides insight into how cultural context interacts with language experience to shape bilingual lexical processing, particularly in situations where one of the languages is undergoing shift and increasingly functions as a carrier of cultural knowledge.

## **Heritage language proficiency, maintenance and shift**

HLs have been defined as minority languages acquired in the home environment within a broader society where another language is dominant (Montrul & Polinsky, 2021). Definitions of HL speakers have varied as a function of linguistic proficiency, language exposure, and sociocultural affiliation. Some scholars define HL speakers as bilinguals who acquire the HL early in life but later become more dominant in the societal language (Polinsky & Scontras, 2020), whereas others emphasize the importance of sustained competence in the HL as a defining criterion (Rothman, 2009; Valdés, 2000). More inclusive perspectives conceptualize HL speakers along a continuum of proficiency, cultural affiliation, and motivation to maintain or reclaim the HL (Van Deusen-Scholl, 2003; Xiao-Desai, 2019). This heterogeneity is reflected in substantial variability in linguistic competence, language use patterns, and attitudes toward the HL (Montrul & Polinsky, 2021).

HL proficiency and maintenance are strongly shaped by patterns of language exposure and use, with increased reliance on dominant societal languages often contributing to attrition (Montrul, 2022; Prentza & Kaltsa, 2020; Fridman et al., 2024; Shabtaev, 2025b). In multilingual environments where multiple heritage and societal languages coexist, language contact may create competition such that increased use of one is associated with reduced use of the other (Aalberse et al., 2019; Siemund, 2023; Shabtaev, 2025a). These processes are also shaped by broader sociocultural factors: the seminal ethnolinguistic vitality theory posits that preservation of minority languages at the community level depends on the combined effects of status, demographic strength, and institutional support (Giles et al., 1977), often to the detriment of minority languages (Bromham et al., 2020; Fishman, 1991). Over time, these interacting forces can weaken intergenerational transmission and contribute to the gradual endangerment of heritage and minority languages, as documented in a wide range of cases worldwide, including Irish, Welsh, and Scottish Gaelic in Europe, as well as numerous Indigenous languages globally (Austin & Sallabank, 2013), and smaller community languages such as Juhuri (Shabtaev, 2025b).

Importantly, beyond linguistic proficiency and exposure, HL speakers' experiences are also shaped by cultural affiliation and identity. Cultural affiliation refers to the extent to which individuals identify with, participate in, and maintain ties to the cultural practices and values associated with their HL (e.g., Hayakawa et al., 2022; De Leersnyder, et al., 2020). This connection is not merely symbolic: a large-scale meta-analysis by Mu (2015), synthesizing 43 datasets across 18 studies and over 3,400 participants from multiple ethnic groups, found a statistically significant moderate positive correlation between HL proficiency and ethnic identity, indicating that stronger HL use is associated with stronger ethnic

identification across diverse communities. The study further suggests that HL serves as a marker of belonging by enabling participation in family relationships, intergenerational communication, and culturally meaningful practices that reinforce ethnic identity over time. More broadly, these findings underscore that HL processing and use are embedded within wider sociocultural experiences.

## Cultural bias and language processing

Cultural context influences lexical access and conceptual activation, but its role in shaping real-time processing across bilingual speakers' languages, particularly in HL contexts, remains unclear. One view posits that culture-specific concepts develop stronger lexical-conceptual links in the language of experience, leading to facilitated access in culturally congruent contexts, with non-congruent contexts showing reverse effects (see Liu et al., 2021). Another view emphasizes online modulation, whereby cultural cues bias language activation and selection processes without altering underlying representations (e.g., Som et al., 2018). These two mechanisms are not mutually exclusive and may operate in parallel.

Empirical evidence supports both accounts across bilingual populations under different research frameworks. Specifically, in studies involving Mandarin-English bilinguals (Jared et al., 2013; Liu et al., 2021), participants responded more quickly when naming or recognizing stimuli in culturally matched contexts (e.g., Chinese-cultural images were named/recognized faster in Mandarin than in English), suggesting that conceptual representations are more strongly connected to the language in which those experiences were formed, and that conceptual activation is sensitive to culturally relevant information. Furthermore, Berkes et al. (2018) and Pan et al. (2021) provide converging behavioral and neurocognitive evidence for cultural congruency effects in bilingual language processing. Across studies, culturally congruent pairings facilitate performance in picture-word matching tasks, with faster responses observed across languages, while ERP findings indicate that such behavioral facilitation is accompanied by modulations in neural responses reflecting sensitivity of semantic processing to culturally congruent contexts or cues. Likewise, exposure to heritage-culture cues in Chinese-English bilinguals has been shown to increase Chinese activation and interfere with English processing, leading to slower responses (Zhang et al., 2013). Nevertheless, the impact of cultural context may depend on factors such as cue salience, task demands, and processing stage, as suggested by findings showing that background cultural images do not always consistently modulate naming or switching costs (Roychoudhuri et al., 2016).

Evidence from eye-tracking studies further suggests that such effects extend to real-time processing, particularly in relation to general contextual information. Karaca et al. (2024) have shown that linguistic cues and cumulative HL exposure influence processing in speakers, with reduced experience potentially leading to weaker or less stable mechanisms. Similarly, studies comparing HLs and SLs in heritage speakers have shown that differences in exposure shape how information is integrated during comprehension, with less dominant languages often showing greater sensitivity to contextual support (Cruz et al., 2025; Valero Fernández et al., 2025). Eye movement patterns further reflect graded

differences in linguistic knowledge, with lower proficiency associated with slower lexical access, increased processing effort, and greater reliance on contextual cues during real-time language processing (Berzak & Levy, 2023; Gollan et al., 2011). Importantly, eye-tracking evidence demonstrates that contextual information can dynamically influence lexical competition as processing unfolds, even when final behavioral outcomes appear similar (Ayasse & Wingfield, 2020). Other studies highlight the importance of lexical properties such as word frequency and general word familiarity in shaping processing efficiency (Juhasz, 2018; Pellicer-Sánchez & Montero Perez, 2024). Together, these findings indicate that variability in language experience modulates the degree to which contextual or culturally relevant information contributes to lexical processing, particularly in populations using multiple languages.

## **The current study: Cultural bias in Mountain Jews in Israel**

The primary objective of the present study was to investigate how cultural bias shapes lexical processing across the two HLs of multilingual adults during spoken word recognition in a visual world eye-tracking paradigm. Specifically, we examined whether culturally congruent lexical items facilitate picture recognition from corresponding auditory prompts, relative to non-congruent and neutral items, and whether such effects generalize. To capture both outcome and process, we analyzed offline performance in terms of recognition accuracy and response speed, alongside online gaze patterns reflecting real-time lexical activation during target identification.

To address this inquiry, Mountain Jews (MJs) provide an excellent test case, as their linguistic repertoire includes two HLs, Juhuri (Judeo-Tat) and Russian, that differ markedly in sociolinguistic status, functional use, and cultural significance. MJs are an ethnoreligious Jewish immigrant community originating from the eastern Caucasus, historically descending from Persian-speaking Jewish populations who settled in the region over many centuries (Brook, 2018; Borjian & Kaufman, 2016; Shabtaev, 2025a,b). Throughout history, MJs maintained a distinct ethnocultural and linguistic identity despite shifting political regimes, including incorporation into the Russian Empire and later the Soviet Union, which led to the growing importance of Russian as a language of wider communication. Large-scale migration of MJs to Israel took place primarily in the 1990s as part of broader post-Soviet immigration waves. As a result, MJs have been characterized by multilingualism involving two HLs: Russian, now considerably more dominant, and Juhuri, the traditional language used within the family and community (Meir et al., 2021; Shabtaev et al., 2022).

The sociolinguistic integration of MJs in Israel has been shaped by both assimilation pressures and strong community cohesion. The hegemonic role of Hebrew within Israeli society promoted linguistic assimilation, particularly among younger generations (Amitay & Shemer, 2024), while cohesive community structures, often supported by residential concentration, facilitated the preservation of cultural traditions and HL knowledge (Shabtaev, 2025b). Within this bilingual context, Juhuri and Russian have played distinct roles in shaping language practices and identity. Juhuri, a Jewish variety of Tat, reflects long-standing contact with Persian as well as Hebrew and Aramaic lexical influence (Shabtaev et

al., 2022). Despite its historical and ethnocultural significance in the MJ community, Juhuri is considered endangered today, with declining numbers of native speakers and reduced intergenerational transmission (Meir et al., 2021). Russification processes in the Soviet period and the centrality of Hebrew in Israel are among the sociopolitical developments that contributed to this decline (Meir et al., 2021; Shabtaev et al., 2022).

Consequently, proficiency in Juhuri varies considerably across generations, with comprehension typically better preserved than production (Shabtaev et al., 2024a). It is used primarily by first-generation immigrants, often in combination with Russian through code-switching, whereas younger speakers rely predominantly on Hebrew and, to a lesser extent, Russian (Borjian & Kaufman, 2016; Shabtaev et al., 2022). Despite its limited functional use, affective attitudes and ethnocultural identity may support partial maintenance, with Juhuri increasingly assuming a symbolic role associated with cultural continuity and group identity (Shabtaev et al., 2024a; 2024b). Consistent with this, culture-specific vocabulary is retained even by less proficient speakers (Shabtaev et al., 2024c). Russian, by contrast, remains highly prominent within the linguistic repertoire of MJs. Spoken by a large immigrant population in Israel, it is supported by broad cultural visibility, including media, commerce, and political representation, making it socially and economically advantageous even among speakers with limited Hebrew proficiency (Meir et al., 2021; Remennick & Prashizky, 2022).

## Method

### Participants

A total of 38 Mountain Jewish adults residing in various cities across Israel participated in the study. Participants' ages ranged from 38 to 69, with a mean age of 47.1 (SD = 6.93) years at the time of testing. The sample included 27 female and 11 male participants. Participants were recruited via convenience sampling, primarily through relatives and members of the *Midor Ledor* organization, which hosts cultural and community events for the Mountain Jewish community. All participants immigrated to Israel during the 1990s, either as children or adults. Participants were balanced across two counterbalanced experimental, with 19 participants assigned to each list. Age of acquisition differed across the three languages. Russian was acquired early by all participants, with 100% reporting acquisition between ages 0–5. Similarly, Juhuri was predominantly acquired in early childhood, with 97.4% of participants reporting acquisition between ages 0–5 and a small minority (2.6%) between ages 13–17. In contrast, Hebrew showed a more distributed pattern of acquisition: 28.9% between ages 6–12, 42.1% between ages 13–17, 23.7% between ages 18–29, and 5.3% after age 30.

Self-reported proficiency in comprehension and production was obtained for Juhuri, Russian, and Hebrew on a 5-point Likert scale ranging from 1 – *No knowledge* to 5 – *Fully fluent*. Table 1 presents self-reported proficiency score for the three languages of the participants.

Table 1  
Self-reported language proficiency and use (mean and standard deviation) across comprehension and production for Juhuri, Russian, and Hebrew.

| Comprehension | Juhuri      | Russian     | Hebrew      |
|---------------|-------------|-------------|-------------|
|               | 4.08 (1.01) | 5.00 (0.00) | 4.79 (0.57) |
| Production    | 3.49 (1.09) | 4.97 (0.16) | 4.63 (0.87) |

A 3 (Language: Juhuri, Russian, Hebrew)  $\times$  2 (Modality: Comprehension, Production) repeated-measures ANOVA was conducted on proficiency scores, using the “*anova\_test*” from the *rstatix* package. The analysis revealed a significant main effect of Language ( $F(2, 4558) = 2147.54, p < .001, \eta^2G = 0.39$ ) and Modality ( $F(1, 2279) = 4175.08, p < .001, \eta^2G = 0.07$ ), as well as a significant Language  $\times$  Modality interaction effect ( $F(2, 4558) = 2122.92, p < .001, \eta^2G = 0.09$ ).

Post-hoc pairwise comparisons (Bonferroni-corrected) indicated that proficiency differed significantly across all three languages for both comprehension and production ( $p < .001$ ), and that comprehension and production differed significantly within each language ( $p < .001$ ). Participants’ self-reported scores were the highest in Russian, followed by Hebrew, and lowest in Juhuri. Juhuri comprehension and production were lower and more variable, whereas Russian and Hebrew scores were high across both modalities

## Materials and procedure

Potential participants were informed about the purpose of the study, particularly its relevance for the documentation and preservation of Juhuri, and were invited to participate voluntarily.

The experiment was administered in one of two languages of choice, Russian or Hebrew, which were used for all instructions, a background questionnaire, and an informed consent form, while the experimental stimuli consisted of Juhuri and Russian auditory materials. The consent form, which initiated the session, informed participants that the study was conducted by the authors and described the general structure of the experiment. Participants were notified that their responses would remain confidential and that they could withdraw at any time by closing the browser tab. All testing took place on the same computer in a quiet environment, using Gorilla Experiment Platform’s web-based eye-tracking, via a “looking while listening” design (Prystauka et al., 2024a). The entire session lasted approximately 10–15 minutes (including calibration and breaks), after which participants were thanked and debriefed. Participants first completed the questionnaire and then proceeded to the eye-tracking experiment, which constituted the main component of the study.

**Questionnaire.** Following consent, participants completed a 14-item (23 items including language-specific rating) background questionnaire assessing linguistic and demographic information. The questionnaire included questions about age, gender, education, profession, and age of immigration or

repatriation. Participants also reported the age of acquisition, first and dominant languages, and contexts of language use.

## Web eye-tracking experiment

After a short calibration phase at the start of each language block, participants were instructed to look naturally at the images on the screen while listening to the auditory questions in the respective language. Each trial was preceded by a fixation cross, after which two images were displayed side by side, and participants' eye movements were recorded from screen onset until the end of the trial (approximately 3 seconds). Participants were instructed to click on the image corresponding to the spoken word while their gaze patterns were recorded. Short breaks were provided between blocks for fixation crosses.

**Auditory stimuli.** Each trial was accompanied by an auditory question of the form “Where is X?”, where X referred to the target item displayed on screen. In Juhuri, the question was “Aji X?” and in Russian, “Gde X?”. Recordings were produced by a proficient female Mountain Jewish Juhuri-Russian speaker in a quiet environment using Audacity. All recordings were carefully synchronized for timing as follows:

- 0.000–0.500: silence
- 0.500–0.970: *aji/gde* (“where”)
- 0.970–1.975: target noun
- 1.975–2.995: silence

This timing structure was applied consistently across all items in both languages to ensure uniform temporal alignment of auditory cues and visual displays.

**Visual stimuli and experimental design.** Cultural stimuli were selected through consultation with members of the relevant speech communities who did not participate in the experiment. For the Juhuri block, ten Mountain Jewish consultants residing in Israel each proposed 15 culturally salient items associated with Mountain Jewish and broader Caucasian cultural practices. Based on overlap and agreement across consultants, a final set of ten culturally biased items was selected. For the Russian block, ten non-Mountain Jewish native speakers of Russian, including two linguists, completed the same procedure, resulting in a comparable set of ten culturally biased items congruent with Russian cultural contexts.

The visual stimuli comprised photorealistic images depicting 10 culturally congruent items (CCI), 10 culturally non-congruent (CNCI), and 10 neutral items per language (Neutral). CCIs were objects or concepts closely associated with Mountain Jewish and broader Caucasian culture in the Juhuri block (e.g., traditional foods, artifacts, or dances), and with Russian cultural contexts in the Russian-language block. CNCIs represented comparable but culturally non-congruent or Westernized counterparts (e.g., a Western dance instead of a traditional one). Neutral items depicted objects or concepts without salient cultural associations. Thus, CCI and CNCI items depicted the same concept (i.e., the same referent) but

differed in their cultural congruency with the given language, whereas neutral items served as unrelated fillers matched with the other conditions for item type (e.g., action, profession, object). Table 2 provides example trials from two sets, showing how conditions were distributed across lists and languages.

Table 2  
Illustration of experimental design and item counterbalancing across languages, sets, and lists.

|                                                                                                                                                                                                                                                                       |      |                 | Juhuri  | Russian    |           |            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----------------|---------|------------|-----------|------------|
| Set                                                                                                                                                                                                                                                                   | List | Condition       | Target  | Competitor | Target    | Competitor |
| 1                                                                                                                                                                                                                                                                     | 1    | CCI-Neutral     | Dance1  | Writing    | Souvenir1 | Pictures   |
|                                                                                                                                                                                                                                                                       |      | CNCI-Neutral    | Dance2  | Laugh      | Souvenir2 | Plates     |
|                                                                                                                                                                                                                                                                       |      | Neutral-Neutral | Writing | Laugh      | Pictures  | Plates     |
|                                                                                                                                                                                                                                                                       | 2    | CCI-Neutral     | Dance1  | Laugh      | Souvenir1 | Plates     |
|                                                                                                                                                                                                                                                                       |      | CNCI-Neutral    | Dance2  | Writing    | Souvenir2 | Pictures   |
|                                                                                                                                                                                                                                                                       |      | Neutral-Neutral | Laugh   | Writing    | Plates    | Pictures   |
| 7                                                                                                                                                                                                                                                                     | 1    | CCI-Neutral     | Sweets1 | Flowers    | Sweets1   | Books      |
|                                                                                                                                                                                                                                                                       |      | CNCI-Neutral    | Sweets2 | Glasses    | Sweets2   | Coins      |
|                                                                                                                                                                                                                                                                       |      | Neutral-Neutral | Flowers | Glasses    | Books     | Coins      |
|                                                                                                                                                                                                                                                                       | 2    | CCI-Neutral     | Sweets1 | Glasses    | Sweets1   | Coins      |
|                                                                                                                                                                                                                                                                       |      | CNCI-Neutral    | Sweets2 | Flowers    | Sweets2   | Books      |
|                                                                                                                                                                                                                                                                       |      | Neutral-Neutral | Glasses | Flowers    | Coins     | Books      |
| <i>Note.</i> The suffixes 1 and 2 indicate culturally congruent (CCI) and non-congruent (CNCI) variants of the same item (e.g., Souvenir1 = matryoshka; Souvenir2 = elephants; Dance1 = Lezginka; Dance2 = Western dance). Neutral items served as unrelated fillers. |      |                 |         |            |           |            |

The experiment included 10 critical item sets, each comprising three conditions that contrasted CCI, CNCI, and neutral items, each preceded by a brief five-point calibration. Stimuli were presented in two language blocks, Juhuri and Russian, using an identical experimental design across languages; only the specific items differed. Each language block consisted of ten critical item sets and two practice sets. In each trial, participants viewed two images displayed side by side while hearing an auditory question referring to one of the images (the target), with the other serving as a competitor.

Each set thus formed a triplet of related trials. Within each set, trials contrasted a CCI paired with a neutral competitor, a CNCI paired with a neutral competitor, and a neutral-neutral pairing. For example, in Juhuri, one set included Dance1 (CCI), depicting a Mountain Jewish/Caucasian dance, and Dance2

(CNCI), depicting a Western dance, each appearing as the target against a neutral item (e.g., Writing or Laugh), alongside a neutral-neutral trial (e.g., Writing-Laugh). In Russian, the same structure was used with souvenir items, where Souvenir1 (CCI) depicted three nested *matryoshka* dolls and Souvenir2 (CNCI) depicted three toy elephants; both appeared as the target against neutral items such as Pictures or Plates, together with a neutral–neutral pairing (e.g., Pictures-Plates). Across all trials, the auditory target always referred to the CCI or CNCI item when present, and to the neutral item used as a competitor against the CCI item as the target in neutral-neutral trials.

To control for item-specific and position effects, stimuli were presented in two counterbalanced lists. Each participant was assigned to one list per language, ensuring that critical items (CCI and CNCI) appeared only once per language block and always as targets. The pairing of critical items with neutral items was swapped across lists. For instance, in Juhuri, in List 1, Dance1 (CCI) was paired with Writing and Dance2 (CNCI) was paired with Laugh, whereas in List 2 these pairings were reversed, such that Dance1 (CCI) was paired with Laugh and Dance2 (CNCI) with Writing. The same counterbalancing logic was applied in Russian, where Souvenir1 (CCI) and Souvenir2 (CNCI) alternated between Pictures and Plates across lists. Neutral–neutral trials were likewise counterbalanced across lists, with target and competitor roles reversed between lists.

Overall, participants completed ten item sets for each language, yielding a total of 30 critical trials per language (CCI-Neutral, CNCI-Neutral, and Neutral-Neutral per set), in addition to practice trials. Trial order was randomized within participants across sets and conditions, and the left-right position of images was randomized across trials. The order of the Juhuri and Russian language blocks was also counterbalanced across participants, ensuring that any potential order effects were distributed evenly across the sample.

All images were AI-generated using Microsoft Designer© and standardized for clarity, style, and size. Items from all conditions were matched for quantity, such that images for a given contrast contained the same number of objects. For example, a *souvenir* image depicted three objects in the CCI and CNCI conditions, countered by three plates or three pictures in the neutral condition; a *dance* image likewise showed the same number of dancers in the CCI and CNCI conditions, countered by an action (e.g., laughing or writing) performed by the same number of people.

In addition, exactly half of the objects (five out of ten) were shared across the two language blocks. Specifically, *food*, *sweets*, *teacup*, *soup*, and *musician* served as culturally biased and non-culturally biased items in both the Juhuri and Russian versions of the experiment, allowing partial overlap in item content while maintaining language-specific cultural instantiations.

## Data analysis

Statistical analyses were carried out using R (R Team, 2026). Accuracy, reaction times, and gaze data were analyzed using mixed-effects models from the lme4 package. Accuracy and target fixations were modeled with generalized linear mixed-effects models (GLMMs), while reaction times were log-

transformed and analyzed with linear mixed-effects models (LMMs). All graphs and figures were created using the *ggplot* function from the *ggplot2* package. Model summaries were generated with the *tab\_model* function from the *sjPlot* package, and post-hoc analyses for the regression models were performed using the *emmeans* function from the *emmeans* package.

All models included random intercepts for Participant and Target to account for variability across individuals and stimuli. Because each trial contained a single target, Target and Trial Number were effectively equivalent; Trial Number was therefore not included separately. Analyses were conducted separately for each language (Juhuri, Russian) to account for potential differences in language proficiency and processing. Fixed effects of interest (e.g., ConditionGeneral) were added to the models, and model comparisons were performed using likelihood ratio tests to assess improvement in fit. Intercepts are omitted because they reflect baseline accuracy (reference condition) and are not substantively interpreted; cross-language comparisons focus on condition effects and variance structure. For models that yielded significant effects, post-hoc comparisons with Tukey corrections were performed.

Following model comparison, accuracy was modeled with GLMMs using a binomial distribution with a logit link. The final formula used for accuracy models was as follows:

```
glmer(Correct ~ ConditionGeneral + (1 | ID) + (1 | Target))
```

Reaction times were calculated as the interval between screen onset (i.e., when the visual stimuli appeared) and the participant's response (first fixation on the correct target or click on the target). All RTs were included without truncation to capture the full range of participant responses, ensuring that both fast and slow responses contributed to the analysis. The auditory prompts ("Where" and the target word) were presented at fixed delays after screen onset, but these delays were identical across all conditions and participants. By anchoring RTs to screen onset, we captured the total processing time including the early anticipatory effects of condition. RTs were log-transformed prior to analysis to reduce skewness and approximate normality. Reaction time models used the following formula:

```
lmer(logRT ~ ConditionGeneral + (1 | ID) + (1 | Target))
```

Target fixations were analyzed with GLMMs using a binomial distribution with a logit link. To model time-course effects, the fixed predictor of condition was observed in interaction with time variable, which was z-scored across trials to improve numerical stability and interpretability. Target look models used:

```
glmer(TargetLook ~ ConditionGeneral*ItemTime + (1 | ID) + (1 | Target))
```

This modeling approach ensured that the main sources of variance were properly accounted for while keeping the models parsimonious and focused on the experimental manipulations of interest.

Our time window of interest for the experiment was from screen onset when images were seen until participants clicked on the desired image. Looks to the target were coded binomially (1 = look to the

target, 0 = look to the competitor/elsewhere) for roughly 50 ms time bins as produced by Gorilla (Prystauka et al., 2024b). For analyses of gaze data, only fixations occurring within a 0–2 second window after target onset (3 seconds after screen onset) were included. Fixations beyond this range were excluded to avoid remaining target looks that are not comparable across trials and to focus on the critical period when participants were actively attending to the screen. This exclusion affected 6.1% of data points in the Juhuri block and 4% in the Russian block. Trials beyond 3 seconds were retained in the dataset for overall analyses of accuracy and RTs but were excluded from plots to prevent disproportionate stretching of the time axis. This approach preserves the temporal dynamics of gaze behavior while maintaining comparability across trials.

## Findings

### Accuracy and RT measures

Table 3 presents descriptive statistics for target identification accuracy and reaction times across conditions and languages. Figures 1 and 2 visualize these results. Overall, accuracy was high in both language blocks, indicating that participants performed the task reliably across all conditions. Reaction times showed systematic variation as a function of condition and language, with broadly comparable response profiles across the Juhuri and Russian blocks. Patterns observed for raw reaction times were mirrored in the log-transformed reaction time measures, suggesting that the effects were not driven by skewness in the response time distributions. Together, these descriptive results indicate stable task performance across conditions, while allowing for condition- and language-related differences in processing speed that are examined further in the inferential analyses.

Table 3

Mean target identification accuracy (SD) and reaction times to the target (SD; milliseconds and log-transformed), by language and condition.

| Language      | Juhuri      |             |             | Russian     |             |             |
|---------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Condition     | CCI–N       | CNCI–N      | N–N         | CCI–N       | CNCI–N      | N–N         |
| Accuracy (SD) | 0.97 (0.18) | 0.97 (0.16) | 0.93 (0.26) | 1.00 (0.07) | 0.99 (0.09) | 1.00 (0.05) |
| RT (SD), ms   | 2509 (1073) | 2562 (747)  | 2808 (1040) | 2451 (543)  | 2491 (962)  | 2388 (570)  |
| log RT (SD)   | 7.79 (0.24) | 7.82 (0.24) | 7.90 (0.25) | 7.78 (0.20) | 7.78 (0.25) | 7.76 (0.21) |

**Accuracy.** The results for Juhuri (Table 4) revealed a significant overall effect of condition on accuracy (both CCI-N and CNCI-N  $p < 0.05$ ). However, subsequent Tukey-adjusted post hoc comparisons revealed only marginally significant differences between the baseline condition and CCI-N ( $p = 0.08$ ), with no reliable difference between N-N and CNCI-N ( $p = .102$ ). No difference was observed between the two experimental conditions (CCI-N vs. CNCI-N:  $p = .98$ ). For Russian, no effect of condition on accuracy was

observed. Neither CCI-N nor CNCI-N differed from the baseline condition ( $p > .90$ ). Accuracy was largely driven by item-level variability, with fixed effects accounting for virtually no variance.

Taken together, the results show a clear cross-language contrast: condition exerted a trend-level influence on accuracy in Juhuri but had no detectable effect in Russian. Moreover, whereas accuracy in Juhuri reflected both fixed and random sources of variation, Russian accuracy was dominated by target-specific effects.

Table 4  
Mixed-effects logistic models predicting accuracy in Juhuri and Russian.

| <b>Predictors</b>                  | <b>Juhuri</b>      |            |              | <b>Russian</b>     |             |          |
|------------------------------------|--------------------|------------|--------------|--------------------|-------------|----------|
|                                    | <b>Odds Ratios</b> | <b>CI</b>  | <b>p</b>     | <b>Odds Ratios</b> | <b>CI</b>   | <b>p</b> |
| CCI-N                              | 4.5                | 1.13–17.85 | <b>0.032</b> | 0.85               | 0.00–479.79 | 0.961    |
| CNCI-N                             | 3.87               | 1.06–14.13 | <b>0.041</b> | 0.79               | 0.00–410.70 | 0.942    |
| <b>Random Effects</b>              |                    |            |              |                    |             |          |
| $\sigma^2$                         | 3.29               |            |              | 3.29               |             |          |
| $\tau_{00}$ Target                 | 1.4                |            |              | 38.15              |             |          |
| $\tau_{00}$ ID                     | 2.65               |            |              | 0.25               |             |          |
| ICC                                | 0.55               |            |              | 0.92               |             |          |
| $N_{ID}$                           | 38                 |            |              | 38                 |             |          |
| $N_{Target}$                       | 40                 |            |              | 40                 |             |          |
| Observations                       | 1140               |            |              | 1140               |             |          |
| Marginal $R^2$ / Conditional $R^2$ | 0.059 / 0.578      |            |              | 0.000 / 0.921      |             |          |

**Reaction Times.** For Juhuri, the results revealed a significant effect of condition on RTs (Table 5). Relative to the baseline condition (N–N), both experimental conditions were associated with faster responses. RTs were significantly shorter in the CCI-N condition ( $p = .001$ ) and in the CNCI-N condition ( $p = .01$ ). Post hoc comparisons confirmed that RTs in both experimental conditions were faster than in the baseline condition (N–N). Specifically, RTs were significantly shorter in the CCI-N condition ( $p = .004$ ) and in the CNCI-N condition ( $p = .036$ ) compared with N–N. No difference was observed between the two experimental conditions (CCI-N vs. CNCI-N:  $p = .737$ ). These results confirm that condition reliably

influenced processing speed in Juhuri, with faster responses in the experimental conditions relative to baseline.

In contrast, no effect of condition on RTs was observed for Russian. Neither the CCI-N nor the CNCI-N condition differed from the baseline condition (both  $ps > .25$ ). RT variability was primarily driven by random effects, with fixed effects accounting for only a minimal proportion of variance.

Overall, the RT results reveal a clear cross-language contrast. Condition significantly influenced processing speed in Juhuri, whereas no such effect was detected in Russian. Moreover, the contribution of fixed effects was greater for Juhuri than for Russian, suggesting that experimental manipulations affected online processing in Juhuri but not in Russian.

Table 5  
Mixed-effects linear models predicting log-transformed RTs in Juhuri and Russian.

| <i><b>Predictors</b></i>              | <b>Juhuri</b>           |                  |                 | <b>Russian</b>          |                  |                 |
|---------------------------------------|-------------------------|------------------|-----------------|-------------------------|------------------|-----------------|
|                                       | <i><b>Estimates</b></i> | <i><b>CI</b></i> | <i><b>p</b></i> | <i><b>Estimates</b></i> | <i><b>CI</b></i> | <i><b>p</b></i> |
| CCI-N                                 | -0.11                   | -0.18 – -0.05    | <b>0.001</b>    | 0.03                    | -0.02–0.08       | 0.258           |
| CNCI-N                                | -0.09                   | -0.15 – -0.02    | <b>0.01</b>     | 0.03                    | -0.02–0.08       | 0.289           |
| <b>Random Effects</b>                 |                         |                  |                 |                         |                  |                 |
| $\sigma^2$                            | 0.04                    |                  |                 | 0.03                    |                  |                 |
| $\tau_{00}$ Target                    | 0.01                    |                  |                 | 0                       |                  |                 |
| $\tau_{00}$ ID                        | 0.01                    |                  |                 | 0.02                    |                  |                 |
| ICC                                   | 0.26                    |                  |                 | 0.4                     |                  |                 |
| $N_{ID}$                              | 38                      |                  |                 | 38                      |                  |                 |
| $N_{Target}$                          | 40                      |                  |                 | 40                      |                  |                 |
| Observations                          | 1140                    |                  |                 | 1140                    |                  |                 |
| Marginal $R^2$ /<br>Conditional $R^2$ | 0.037 / 0.287           |                  |                 | 0.003 / 0.405           |                  |                 |

## Target look analysis

Figure 3. Visual display of gaze development across conditions over time for Juhuri (upper panel) and Russian (lower panel). Vertical dashed lines indicate key events: screen onset (~1000 ms), onset of the auditory prompt “where?” (~500 ms), and onset of the target word (0 ms).

For Juhuri, gaze increased over the course of the trial, and condition significantly interacted with time, indicating that the temporal pattern of looking varied across conditions. Specifically, Time significantly predicted target-looking ( $p < 0.001$ ), and there was a significant interaction between CNCI-N and time ( $p = 0.01$ ), while the CCI-N  $\times$  time interaction was not significant ( $p = 0.34$ ). Main effects of condition were not significant (CCI-N:  $p = 0.44$ ; CNCI-N:  $p = 0.57$ ).

For Russian, gaze also increased over the trial, with significant Condition  $\times$  Time interactions. Time significantly predicted target-looking ( $p < 0.001$ ), and interactions with time were significant for CCI-N ( $p = 0.005$ ) and marginal for CNCI-N ( $p = 0.067$ ). Main effects of condition were not significant (CCI-N:  $p = 0.079$ ; CNCI-N:  $p = 0.856$ ). Post hoc comparisons (see Appendix A1) were conducted at empirically defined time points: the mean of all samples before word onset, followed by the mean of each 500 ms interval after onset (0–500, 500–1000, 1000–1500, 1500–2000 ms). These analyses revealed that condition differences emerged gradually after word onset. In the 1000–1500 ms window, target-looking was higher for CCI-N than N–N ( $p = 0.030$ ) and for CCI-N relative to CNCI-N ( $p = 0.026$ ). These differences increased in the 1500–2000 ms window (CCI-N vs. N–N:  $p = 0.014$ ; CCI-N vs. CNCI-N:  $p = 0.006$ ). No significant contrasts were observed in the pre-word or earliest post-onset windows ( $p > 0.17$ ).

Overall, these results (see Table 6) indicate that condition influenced the temporal development of gaze rather than overall target-looking, with differences emerging primarily in the later stages of the trial, particularly for the CCI-N condition.

Table 6  
Generalized mixed-effects linear models predicting target looks in Juhuri and Russian.

| <i><b>Predictors</b></i>           | <b>Juhuri</b>             |                  |                   | <b>Russian</b>            |                  |                   |
|------------------------------------|---------------------------|------------------|-------------------|---------------------------|------------------|-------------------|
|                                    | <i><b>Odds Ratios</b></i> | <i><b>CI</b></i> | <i><b>p</b></i>   | <i><b>Odds Ratios</b></i> | <i><b>CI</b></i> | <i><b>p</b></i>   |
| CCI-N                              | 0.93                      | 0.76–<br>1.13    | 0.444             | 1.16                      | 0.98–<br>1.38    | <b>0.079</b>      |
| CNCI-N                             | 0.94                      | 0.77–<br>1.15    | 0.568             | 1.02                      | 0.86–<br>1.20    | 0.856             |
| Time                               | 1.27                      | 1.24–<br>1.30    | <b>&lt; 0.001</b> | 1.32                      | 1.28–<br>1.36    | <b>&lt; 0.001</b> |
| CCI-N × Time                       | 1.02                      | 0.98–<br>1.06    | 0.342             | 1.06                      | 1.02–<br>1.11    | <b>0.005</b>      |
| CNCI-N × Time                      | 1.05                      | 1.01–<br>1.09    | <b>0.011</b>      | 0.96                      | 0.92–<br>1.00    | <b>0.067</b>      |
| <b>Random Effects</b>              |                           |                  |                   |                           |                  |                   |
| $\sigma^2$                         | 3.29                      |                  |                   | 3.29                      |                  |                   |
| $\tau_{00}$ Target                 | 0.07                      |                  |                   | 0.05                      |                  |                   |
| $\tau_{00}$ ParticipantID          | 0.06                      |                  |                   | 0.06                      |                  |                   |
| ICC                                | 0.04                      |                  |                   | 0.03                      |                  |                   |
| $N_{\text{ParticipantID}}$         | 38                        |                  |                   | 38                        |                  |                   |
| $N_{\text{Target}}$                | 40                        |                  |                   | 40                        |                  |                   |
| Observations                       | 66572                     |                  |                   | 63600                     |                  |                   |
| Marginal $R^2$ / Conditional $R^2$ | 0.020 / 0.057             |                  |                   | 0.025 / 0.056             |                  |                   |

To examine whether language proficiency predicted overall target-looking, we tested mixed-effects models with proficiency as a continuous predictor in Juhuri. Due to pronounced ceiling effects in Russian proficiency scores, analyses for Russian were not conducted. In Juhuri, proficiency did not significantly predict target-looking (OR = 0.96, 95% CI [0.89, 1.03],  $p = .26$ ). However, significant interactions between Juhuri proficiency and condition indicated that higher proficiency was associated with increased target-looking in the CCI-N and CNCI-N conditions relative to the N-N baseline. Full model results and visualizations of the interaction effects are reported in Appendixes A2 and A3.

## Discussion

The present study investigated the role of cultural bias in lexical processing in two HLs, Juhuri and Russian. A consistent asymmetry emerged between the two languages, suggesting that language dominance modulates the effects of cultural bias: in Russian, online measures (eye movements) showed an advantage for cultural congruent items; in Juhuri, offline measures (accuracy and RT measures) showed comparable advantages for both congruent and non-congruent items relative to neutral items. Differences between online and offline measures are frequently observed in bilingual processing research and may reflect the fact that end-state behavioral outcomes do not always capture subtle processing differences emerging during earlier stages (Büyükyıldırım et al., 2025; Fridman & Meir, 2025; Prystauka et al., 2024a). In line with previous findings, and specifically within the HL system, the present findings suggest that less dominant languages may rely more strongly on general contextual support, whereas more dominant languages rely on automatized lexical access (Valero Fernández et al., 2025).

## **Automatic integration of cultural information in a dominant language: Evidence from Russian**

Cultural bias influenced processing in Russian primarily at the level of real-time attention rather than end-state performance, likely reflecting highly automatized lexical processing. Since Russian was rated as participants' more dominant language, with self-reported proficiency scores showing pronounced ceiling effects, the absence of condition effects in accuracy and reaction times is not surprising. As the primary language reported by the participants, Russian likely contributes to stable lexical representations (Fridman & Meir, 2025; Meir et al., 2021; Shabtaev et al., 2024a). Consequently, the present items, referring to everyday objects and actions, are likely to involve familiar and frequently used lexical items that are typically processed rapidly and accurately in dominant languages, thereby reducing variability for experimental manipulations to influence overall performance (Juhasz, 2018; Pellicer-Sánchez & Montero Perez, 2024). From this perspective, the lack of condition-related differences in offline measures does not indicate absence of sensitivity to cultural bias, but rather speaks to efficient lexical processing in the dominant language.

The processing advantage of culturally congruent items in Russian, as shown in eye-tracking results, reflects strong integration of culturally relevant knowledge into lexical representations. Specifically, Russian CCIs elicited increased target looking against the neutral competitors in later time windows (1000–2000 ms after word onset), significantly more than in the other (CNCI-N and N-N) conditions, suggesting that cultural bias influenced processing after initial lexical access had already taken place. In other words, within a second upon hearing the audio stimulus, participants looked increasingly more to the culturally congruent target against the neutral item than they did when the target was culturally non-congruent or a neutral item. Thus, online measures reveal modulation of processing by culturally relevant information despite high automaticity, consistent with evidence that eye-tracking can detect subtle processing differences not always reflected in accuracy or reaction times (Ayasse & Wingfield, 2020; Fridman & Meir, 2025).

This pattern is in line with the idea that extensive exposure and high proficiency contribute to more automatized lexical representations, facilitating rapid and efficient online processing (Cruz et al., 2025; Karaca, 2024). More broadly, this interpretation is situated within the sociolinguistic position of Russian in the MJ community in view of the ethnolinguistic vitality theory (Giles et al., 1977). Russification processes back in the Soviet Union, along with continued prominence of the language in public and institutional spheres in Israel, made Russian the primary *lingua franca* within the community across generations (Giles et al., 1977; Remennick & Prashitzky, 2022; Shabtaev et al., 2024b; Shabtaev, 2025a). As a result, Russian is largely used across communicative domains, from informal everyday home interaction to more formal key institutions, as well as sustained exposure through literature, film, and music. This sociolinguistic profile is likely to result in deeply entrenched associations between language and culturally specific knowledge, consistent with evidence that language experience and cultural exposure modulate access to contextually grounded information through cultural affiliation (Hayakawa et al., 2022; Cruz et al., 2025; Shabtaev et al., 2024c; Zhang et al., 2013).

From a broader psycholinguistic perspective, these findings provide empirical support for lexical-conceptual strength accounts, according to which stronger associations develop between culturally specific concepts and their lexical representations in the language in which they were acquired (Jared et al., 2013; Liu et al., 2021; Zhang et al., 2013). This is reflected in the rapid, online sensitivity to culturally congruent information observed in the eye-tracking measures, consistent with ERP and behavioral evidence of culturally modulated processing during real-time comprehension (Berkes et al., 2018; Pan et al., 2021; Ayasse & Wingfield, 2020). Such effects align with findings that bilinguals process culturally congruent stimuli more efficiently when language and cultural context match, and that language dominance modulates processing efficiency and contextual reliance (Jared et al., 2013; Valero Fernández et al., 2025).

## **Culturally supported processing in a weaker, endangered HL: The case of Juhuri**

Effects of cultural bias for Juhuri emerged only in end-state results, with higher accuracy and slower performance in both culturally congruent and culturally non-congruent conditions relative to the neutral baseline, and no difference between these two non-neutral target conditions. Since culturally congruent and culturally non-congruent items represent the same conceptual objects or referents, the comparable facilitation observed for these two conditions suggests that performance advantages in Juhuri were driven not exclusively by cultural bias, but more broadly by the presence of a semantically informative (non-neutral) contrast supporting lexical identification. This is consistent with evidence that processing in less dominant languages relies more strongly on contextual information (Berzak & Levy, 2023; Cruz et al., 2025; Valero Fernández et al., 2025). In this sense, the observed pattern appears to reflect broader contextual scaffolding rather than cultural bias per se.

Cultural bias did not reliably modulate real-time processing in Juhuri. This pattern is consistent with reduced processing automaticity associated with less dominant languages, which may increase

variability in lexical access and limit the strength of experimentally induced contrasts (Berzak & Levy, 2023; Karaca, 2024). From a broader sociolinguistic standpoint, this outcome may also reflect long-term processes of shift and endangerment, which weaken knowledge of cultural cues (Cruz et al., 2025; Valero Fernández et al., 2025; Shabtaev, 2025a). The observed asymmetry between comprehension and production abilities for Juhuri indicates limited exposure and fewer opportunities for active use (Montrul, 2022; Prentza & Kaltsa, 2020; Shabtaev et al., 2024a), resulting in less robust conceptual-lexical mappings which attenuate the influence of cultural cues during processing (Berzak & Levy, 2023).

Individual differences in Juhuri proficiency help contextualize the parallel advantage of congruent and non-congruent forms over neutral items. As a weaker language with variable proficiency, Juhuri may rely on individual processing strategies, where higher proficiency is associated with better processing of culturally biased (congruent and non-congruent) items due to their general familiarity and contextual-cultural relevance (Berzak & Levy, 2023; Juhasz, 2018; Shabtaev et al., 2024c). Conversely, lower proficiency is often associated with slower lexical access and greater processing effort, which can reduce the immediacy with which contextual information is integrated during processing (Berzak & Levy, 2023; Cruz et al., 2025; Gollan et al., 2011; Karaca, 2024). Moreover, participants are less confident or less practiced in using Juhuri, so while cultural information may be available, it requires stronger evidence to influence decision-making and is more susceptible to modulation by factors such as task demands, cue salience, and processing stage (Roychoudhuri et al., 2016). On the whole, the role of proficiency further indicates that greater language knowledge is associated with more efficient use of contextual and culturally grounded information during lexical processing, in line with findings that experience modulates the integration of contextual and linguistic cues during real-time processing (Karaca et al., 2024; Ayasse & Wingfield, 2020).

The observed findings can therefore be further understood in light of Juhuri's predominant presence in informal communicative contexts, often in code-switching from Russian (Shabtaev et al., 2022) and rarely exclusively (Shabtaev, 2025). Juhuri, in this sense, is a culturally charged language, strongly preserved for colloquial items embedded in culturally salient domains, such as family interactions and community events, while neutral or more formal vocabulary is less frequently used and therefore less readily accessible (Shabtaev et al., 2024c). Performance is therefore primarily driven by general familiarity and contextual integration rather than cultural bias per se, with any informal, non-neutral item proving beneficial, regardless of cultural specificity. By way of example, the item *Dance*, whether representing a Caucasian dance or any other dance type, is a culturally charged word in view of the strong presence of Juhuri in family events and celebrations like weddings, as opposed to neutral competitor items representing actions such as *Writing*, which are more strongly tied to formal communication and are less developed in everyday use. Mirroring key aspects of cultural engagement among HL speakers (De Leersnyder et al., 2020; Xiao-Desai, 2019), this account is in line with previous work on MJs showing enhanced recognition of culture-specific Juhuri vocabulary among younger speakers (Shabtaev et al., 2024c) as well as systematic code-switching to other languages for formal or institutional purposes (Shabtaev et al., 2022).

# Limitations and future research

Several limitations should be acknowledged. High overall accuracy suggests that the task may not have been sufficiently demanding to reveal stronger condition differences. In addition, because Juhuri is not represented in available linguistic corpora, objective frequency measures for the selected lexical items could not be obtained. Although the present study provides an initial validation of culturally biased items through community consultation, future research should complement this approach with rating scales assessing perceived familiarity, cultural relevance, and acquisition timing. Future studies should also further examine how identity-related factors interact with proficiency to shape the integration of cultural information in bilingual lexical processing. Overall, the study underscores the role of cultural knowledge as an integral component of bilingual lexical representations and highlights how differences in language experience influence the efficiency with which such information is accessed, particularly in heritage and endangered language contexts.

## Conclusions

The present study demonstrates that cultural information systematically influences bilingual lexical processing, but that its impact varies as a function of language status and dominance. Cultural bias facilitated processing in both Russian and Juhuri, indicating that culturally grounded conceptual knowledge is available across languages, but differs in the efficiency with which it is accessed. Specifically, facilitation varied as a function of temporal dynamics. In Russian, congruent cultural effects emerged in online gaze measures, suggesting relatively rapid and automatic integration of culturally relevant information during lexical access. In contrast, in Juhuri, effects appeared primarily in reaction times and accuracy, with culturally neutral items producing slower and less accurate responses. Notably, although proficiency supports access to culturally grounded vocabulary in Juhuri, neutral items remain comparatively difficult to process even for relatively proficient speakers, suggesting that non-neutral, contextually relevant information irrespective of congruency provides a primary route for facilitating lexical processing.

These patterns reflect the distinct sociolinguistic profiles and communicative functions of the two languages. Russian enjoys a strong status as a vital and dominant community language among MJs, used across both informal and formal domains. Its historical role as the primary language of the community has gradually relegated Juhuri to an endangered home-based HL, making linguistic knowledge in it increasingly concentrated in culture-based domains for informal communication. The findings thus support empirical lexical-conceptual accounts, according to which culture-specific concepts are more strongly linked to their lexical representations in the congruent language, and further extend this framework to heritage language research, a context in which such effects have been comparatively underexplored. By examining two coexisting heritage languages, one of which is endangered and characterized by reduced vitality and limited domains, the study contributes to a better understanding of how linguistic experience and cultural context jointly shape lexical access in bilingual speakers.

# Declarations

## Funding

No funding was received for conducting this study.

## Competing interests

The authors declare no competing interests.

## Ethics approval

The study was approved by the Human Subjects Institutional Review Board (HSIRB) at Bar-Ilan University (approval no. 251224400). All participants provided informed consent prior to participation.

## Data availability

The data, visual materials, and analysis scripts are available at [https://osf.io/pfa3r/overview?view\\_only=c2f358e1cf9e4a178fce29ff3118b799](https://osf.io/pfa3r/overview?view_only=c2f358e1cf9e4a178fce29ff3118b799)

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Figures

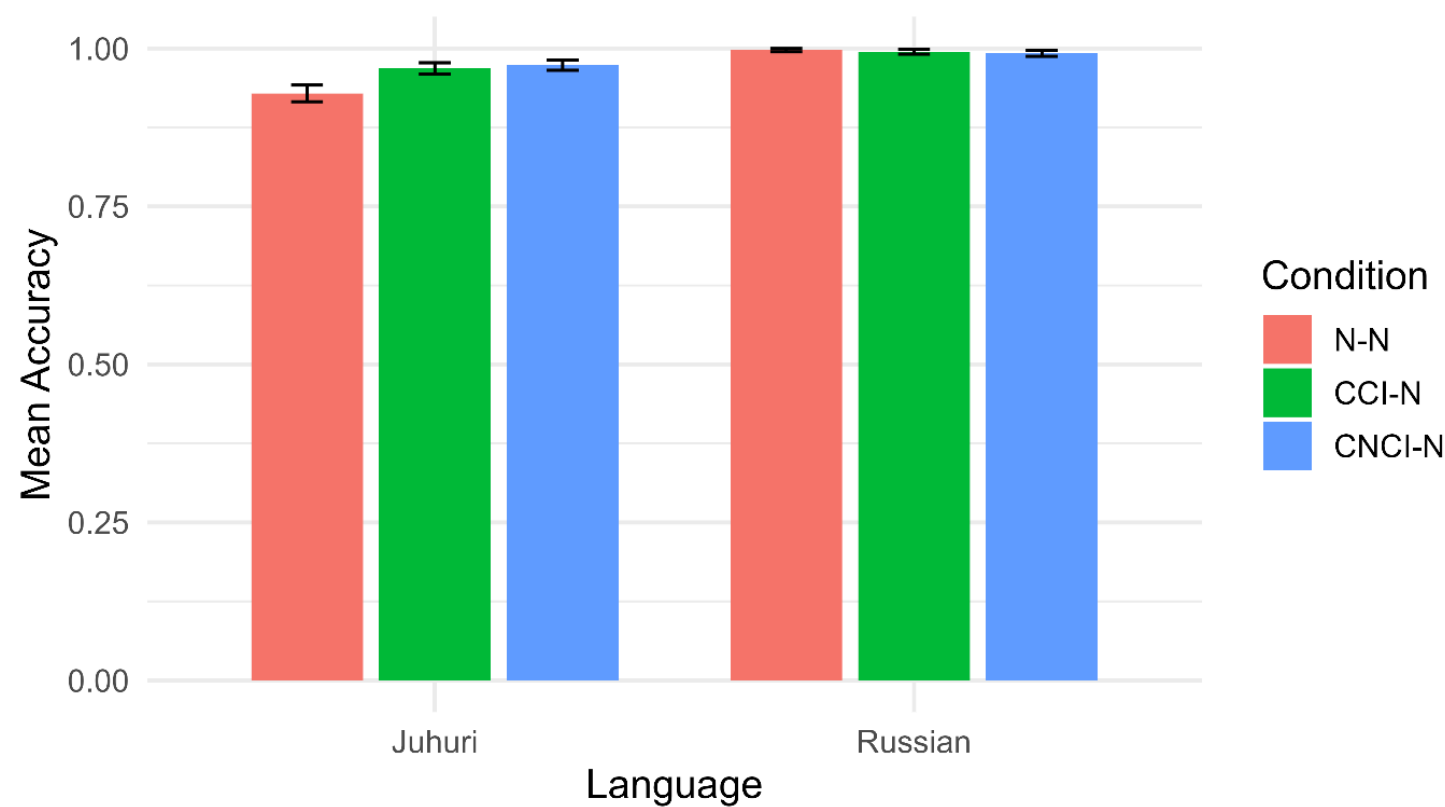


Figure 1

Mean target identification accuracy across conditions and languages. Error bars represent standard errors

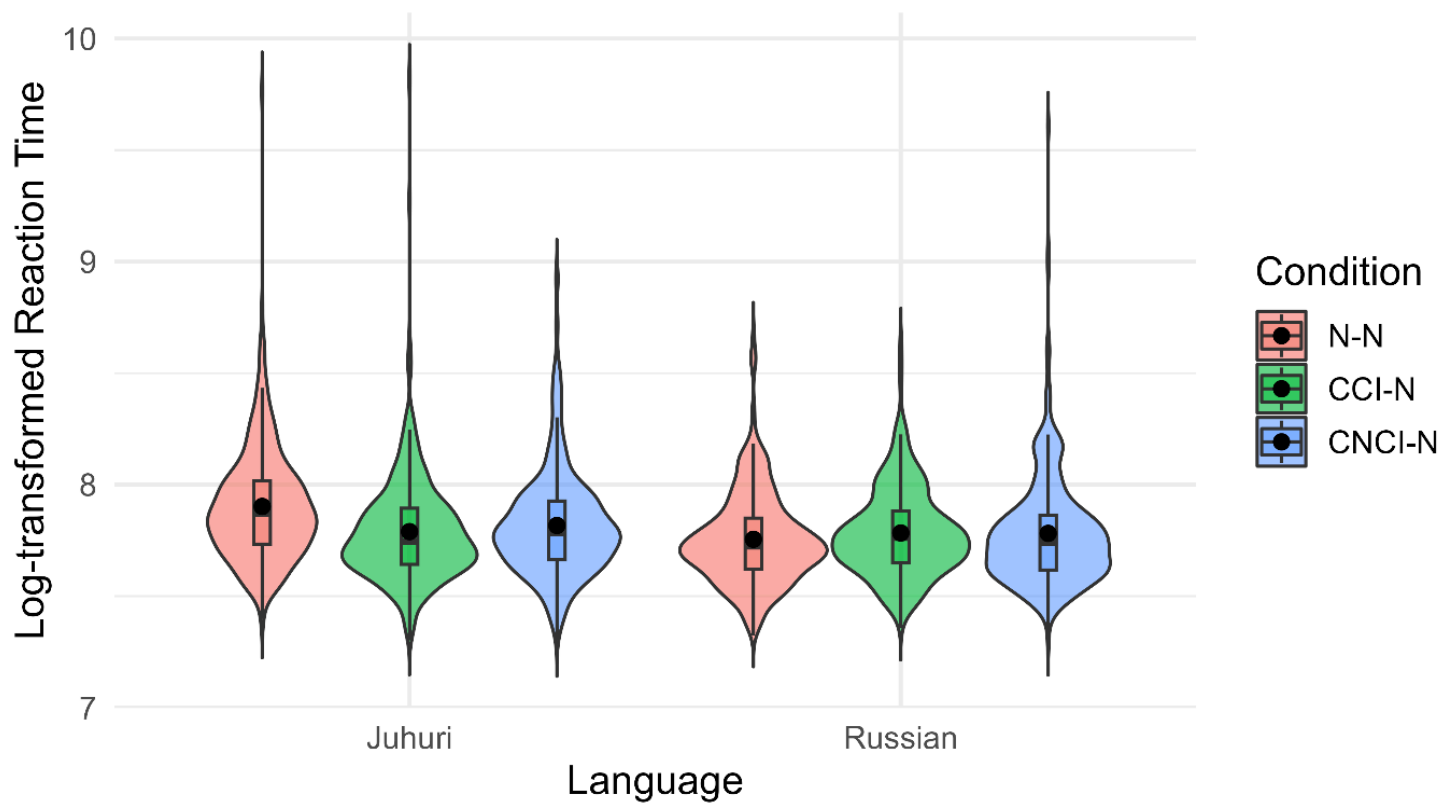


**Figure 2**

Violin plots of log-transformed reaction times by condition and language, with embedded boxplots (median and IQR) and mean points.

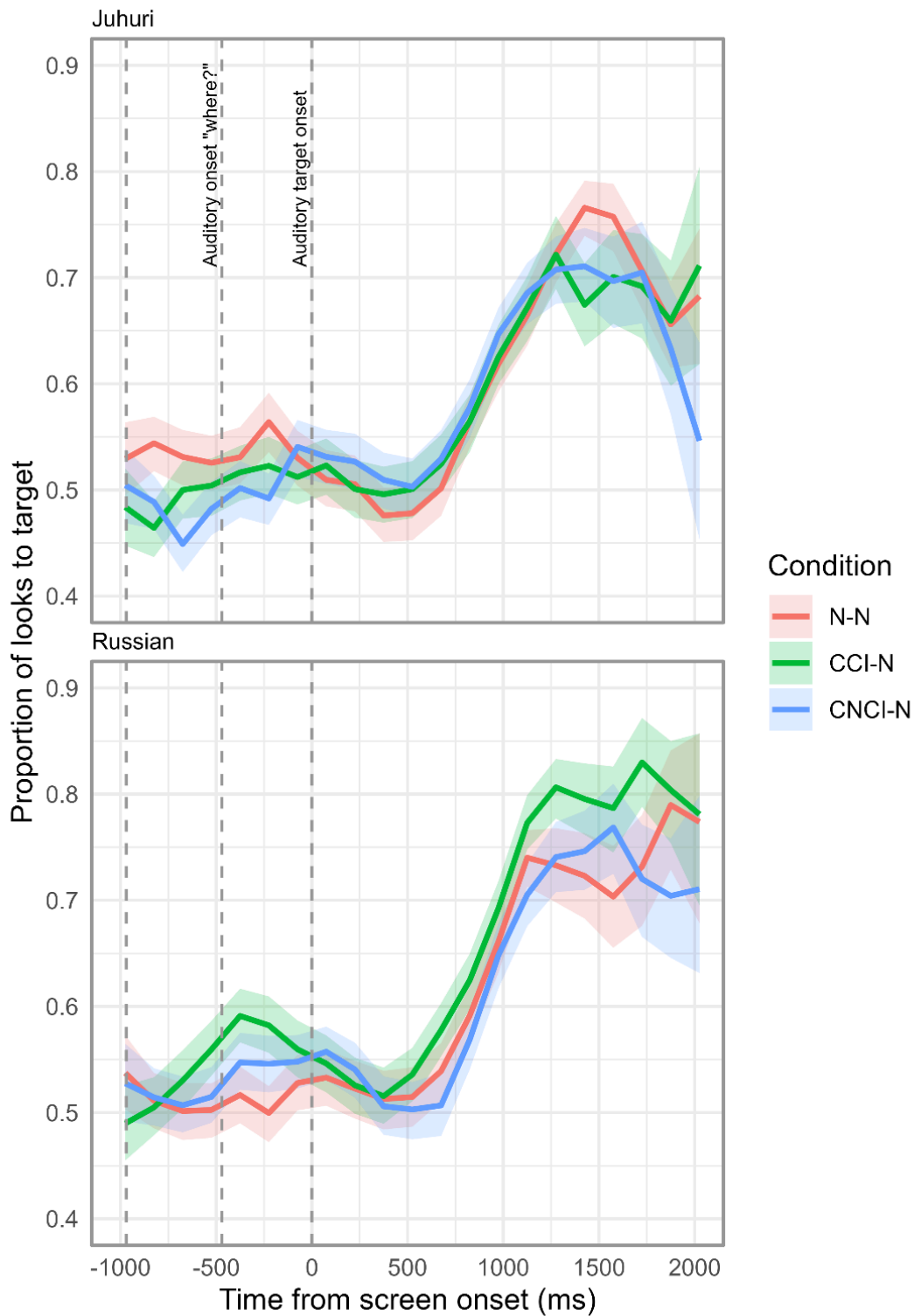


**Figure 3**

Visual display of gaze development across conditions over time for Juhuri (upper panel) and Russian (lower panel). Vertical dashed lines indicate key events: screen onset (~-1000 ms), onset of the auditory prompt “where?” (~-500 ms), and onset of the target word (0 ms).

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [ShabtaevMeirAppendix.docx](#)