Cross-Language Transfer in Cross-Country Contexts: Examining Longitudinal Relationships between Urdu Phonological Processing and English Reading in Pakistan and Canada

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Declaration of Interest

No conflicts of interest, financial or otherwise, are declared by the authors.

Acknowledgements

This project is supported by a Canada Graduate Scholarship – Doctoral Program by the Social Sciences and Humanities Research Council of Canada and an Ontario Graduate Scholarship, which were awarded to IB, as well as a Social Sciences and Humanities Research Council of Canada (SSHRC) Insight Grant (#435-2024-0713) awarded to MM. We are grateful

to the Icon for Child and Adult Nurturing (ICAN) for their support with participant testing in Pakistan.

Abstract

Purpose: This study examines whether kindergarten-level Urdu phonological processing predicts the future Grade 1 English word and non-word reading accuracy skills of Urdu-English bilinguals in (i) Pakistan, with an Urdu as a national/societal-language country context, and (ii) Canada, with an Urdu as a heritage-language country context. **Method:** At Timepoint 1 of this longitudinal study, we assessed 154 Urdu-English kindergarten-aged bilinguals in Pakistan (n = 104) and Canada (n = 50) on their Urdu phonological awareness and rapid automatized naming (RAN) skills, via the Urdu Phonological Tele-Assessment Tool (U-PASS). After 1 year at Timepoint 2, we tested their English word and non-word reading accuracy skills at the Grade 1 level. **Result:** Our hierarchical linear regressions consistently demonstrated cross-language transfer between Urdu phonological awareness and the English word and non-word reading accuracy measures in both Pakistan and Canada. Predictive strength differences were demonstrated between RAN and reading outcomes, based on country-specific contexts. **Conclusion:** Our findings demonstrate that

languages learnt in both a societal or heritage context (i.e., Urdu) contribute to early reading skills in another language (i.e., English), thereby emphasizing the importance of overall cross-language knowledge at the early stages of learning to read. This study also emphasizes the role of cross-language transfer for facilitating equitable access to early assessment for bilingual populations: Urdu phonological processing skills can be used to identify bilingual children's future English reading abilities, rather than waiting until the child demonstrates adequate English language proficiency for completing traditional English phonological processing assessments.

Keywords: Bilingualism; Children; Cross-Language transfer; Phonological processing; Reading; Urdu

INTRODUCTION

Cross-Language Transfer of Pre-Reading Skills for Word Reading in Bilingual Children

Phonological processing is a meta-linguistic skill, which involves conscious awareness and manipulation of language-specific linguistic structures via language-general cognitive processes. The pre-reading skill is critical for learning to read (Veil & Everatt, 2005; Melby-Lervåg & Lervåg, 2011; Chung et al., 2018). In bilingual children, phonological skills in one language have been found to contribute to reading in the other language (Melby-Lervåg & Lervåg, 2011; Chung et al., 2018). This process is known as cross-language transfer (Chung et al., 2018).

Specific to reading outcomes, cross-language transfer occurs when pre-reading skills acquired in one language, such as Urdu, influence reading abilities in the other language, such as English, of bilingual children. Theories of cross-language transfer emphasize various contributing factors for transfer of pre-reading skills to reading abilities across languages (Chung et al., 2018). These include home/heritage (L1) and societal/educational (L2) language proficiency (*Linguistic Interdependence Framework [LIH]*, Cummins, 1981; *Transfer Facilitation Model*, Koda, 2008), degree of linguistic distance (i.e., phonological and orthographic similarities between the two languages; *Contrastive-Typological Framework*, Lado, 1964; *Transfer Facilitation Model*, Koda, 2008; *Contrastive Analysis Hypothesis [CAH]*, Zaretsky, 2016), and the type of assessed pre-reading skill (i.e., whether it is a language-general skill, such as phonological processing, that involves shared underlying cognitive processes across the two languages, or a language-specific skill, such as expressive vocabulary, that involves lexical items specific to a language; *Common Underlying Cognitive Process*, Geva & Ryan, 1993; *Transfer Facilitation Model*, Koda, 2008). Of relevance to the current study is that all of these theories posit that word-level reading involves cognitive and linguistic processes, including meta-linguistic pre-reading skills, that are transferred across languages (Chung et al., 2018; Verhoeven et al., 2019; Gholamain & Geva, 2008). Particularly, the Central Processing Hypothesis (Durgunoğlu, 2002; Durgunoğlu et al., 1993), the Common Underlying

Cognitive Process (Geva & Ryan, 1993), and the Transfer Facilitation Model (Koda, 2008) highlight underlying language-general cognitive processes as the basis for cross-language transfer of phonological processing across linguistically close and distant languages in bilingual children.

However, current reading and cross-language transfer theories are English-centric, or based on languages such as Spanish, French and Italian which share cognate words, a common orthographic script, and linguistic similarities with English (Vaid et al., 2022a; Vaid 2022b; Bonifacci & Tobia, 2017). There can be increased potential for cross-language transfer in related/linguistically-close languages with similar scripts (Melby-Lervåg & Lervåg, 2011). As such, these research findings may not be directly generalizable when investigating transfer between linguistically-distant language combinations, such as from Urdu to English as in our study (Contrastive-Typological Framework and Contrastive Analysis Hypothesis [CAH]; Lado, 1964; Zaretsky, 2016).

Phonological Processing: An Important Pre-Reading Skill Across Languages

Role in Early Word-Level Reading

Phonological processing is an important predictor of early reading (Hogan et al., 2005; Hjetland et al., 2017; Landerl et al., 2019; O'Brien et al., 2019). This foundational pre-reading skill includes *phonological awareness* (i.e., the ability to recognize and manipulate the sound segments present in spoken language) and *rapid automatized naming* ([RAN] i.e., the

ability to rapidly name a series of familiar stimuli such as letters). Phonological awareness enables children to understand the systematic relationship between written and oral language, and acquire symbol (grapheme) - sound (i.e., phoneme) mapping principles in alphabetic orthographies such as Urdu and English (Hjetland et al., 2017; Lonigan et al., 2013; Lonigan et al., 2018). During early reading acquisition, children are often explicitly taught the systematic symbol – sound mappings/correspondences between a written symbol (e.g., grapheme such as letters) and the associated speech-sound (e.g., phoneme or syllable). Developing readers of alphabetic orthographies, such as Urdu and English, apply these learned grapheme - phoneme correspondences (GPCs) to decode unfamiliar written words, by identifying and sounding out letters (i.e., graphemes) and sequentially blending together their individual sounds (i.e., phonemes; Hjetland et al., 2017; Lonigan et al., 2013). Rapid automatized naming (RAN) involves serial processing and rapid retrieval of visual stimuli, including orthographic (i.e., print) and associated phonological (i.e., sound) information. The cognitive processes involved in RAN also underlie reading, and enable children to efficiently retrieve and recognize stored GPCs, word components, and whole words from long-term memory during word-level reading and recognition (Papadopoulos et al., 2016; Vander Stappen & Van Reybroek, 2018).

Cross-Language Transfer of Phonological Processing Skills

Previous studies have demonstrated cross-language transfer effects for phonological processing skills in relation to word-level reading outcomes in bilingual children (Durgunoğlu, 2002; Durgunoğlu et al., 1993; O'Brien et al., 2019; Wawire & Kim, 2018). For example, cross-language predictions were observed from phonemic awareness and RAN in the heritage-language (L1) to English word/non-word decoding among Spanish-English, Portuguese-English and Chinese-English bilingual children (Gottardo et al., 2016). Cross-language transfer effects were also evident for Chinese syllable-level phonological awareness in relation to Dutch word decoding (Yuan et al., 2021). Cross-language transfer was observed between different types of orthographic systems (i.e., whether alphabetic or morpho-syllabic) and regardless of the degree of linguistic distance (i.e., the percentage of shared cognates or linguistic structures across languages) across bilingual language combinations (Gottardo et al., 2016; Yuan et al., 2021). In line with cross-language transfer theories, Melby-Lervåg and Lervåg's (2011) meta-analysis demonstrated moderate associations between heritage-language phonological processing and societal-language word-level decoding across linguistically close and distant languages among children from kindergarten to Grade 8. As compared to language-specific oral-language skills such as vocabulary, phonological processing involves both language and cognition-based components. Cross-language transfer of phonological processing skills for reading outcomes is therefore less dependent on the degree of linguistic distance between bilingual language

combinations — as compared to cross-language transfer effects for vocabulary skills (Melby-Lervåg & Lervåg, 2011). This is due to underlying language-general cognitive processes that facilitate transfer of meta-linguistic skills, such as phonological processing, across both linguistically close and distant languages (Chung et al., 2018; the Central Processing Hypothesis [Durgunoğlu, 2002; Durgunoğlu et al., 1993]; the Common Underlying Cognitive Process [Geva & Ryan, 1993]; the Transfer Facilitation Model [Koda, 2008]).

Implications for Facilitating Access to Early Pre-Reading Assessment in Bilingual Children

Young children's phonological processing skills are commonly measured to predict their future reading abilities and identify potential future reading difficulties (Swank & Catts, 1994; Hogan et al., 2005; Westerveld, 2013). Globally, bilingual children do not have equitable access to such early pre-reading assessment, as most of these assessments are available in Germanic and Romance languages, such as English, Spanish, or French (Ascenzi-Moreno & Seltzer, 2021; Fannin, 2024; Goldstein & Kohnert, 2005; Williams & McLeod, 2012; Rose at al., 2022). Due to the lack of appropriate heritage-language assessment tools, SLPs are limited to assessing bilingual children only in their societal/educational language – English, rather than comprehensively considering both the heritage and societal languages (Williams & McLeod, 2012; Rose at al., 2022). Schoolboards in English-speaking countries, such as the United States and

Canada, often operate within a ‘wait to see’ assessment and intervention approach, particularly for bilingual children with limited English proficiency. This approach results in delayed pre-reading assessment for up to 3-4 years. As a result, assessment is not provided until the child exhibits significant reading deficits, often in Grades 3-4, and demonstrates sufficient language proficiency to complete standardized English assessments (Kidder, 2022; Education Commission of the States, 2023a; Education Commission of the States, 2023b; National Center on Improving Literacy, 2024; Ontario Human Rights Commission, 2023). The lack of early pre-reading assessment delays access to early intervention, and has long-term personal and societal ramifications (Wolf et al., 2005; Kim et al., 2014). At the individual level, these ramifications include long-term academic difficulties, decreased career prospects and socio-economic mobility, and poorer physical and mental health outcomes (Wolf et al., 2005; Kim et al., 2014). At the societal-level, lack of access to early pre-reading assessment, and in turn intervention, is associated with increased incarceration rates and decreased Gross Domestic Product (GDP per capita) and employment rates across countries (Coulombe, 2004; Foley, 2001; Ritchie & Bates, 2013). These findings highlight the importance of timely pre-reading assessment, including examining phonological processing skills in the heritage-language, to support reading development in the educational language of young bilingual children (Kim et al., 2014; Ritchie & Bates, 2013).

As mentioned above, phonological processing in one language predicts pre-reading skills and future reading development in the other language of bilingual children (Durgunoğlu, 1993; Patel et al., 2022; Bhalloo & Molnar, 2021). As such, bilingual children, who require additional early reading supports, can be identified for further support through assessing pre-reading skill abilities, such as phonological processing, in one or both of their heritage and societal/educational languages (Bialystok, 2007; Bhalloo & Molnar, 2021; Westerveld, 2014). Particularly relevant to our study is that pre-reading skills in the heritage-language can be used as a reliable indicator of future reading abilities in the societal/educational language of bilinguals – even in linguistically-distant language combinations such as Urdu and English (Bhalloo & Molnar, 2021; Bhalloo & Molnar, 2023; Bhalloo & Molnar, 2024; Melby-Lervåg & Lervåg, 2011).

Under-Represented Heritage Languages: Urdu

Only a small number of studies have examined cross-language transfer of Urdu phonological awareness and RAN in relation to the English word and non-word level reading skills of bilingual children (Mirza & Gottardo, 2023; Mirza & Gottardo, 2022; Mirza et al., 2017) – despite the fact that Urdu is commonly spoken globally (Eberhard et al., 2021). Out of these, only one Urdu reading study was longitudinal (Mirza & Gottardo, 2023). The longitudinal study (Mirza & Gottardo, 2023) examined cross-language transfer between Urdu phonological awareness and English word reading accuracy of Urdu-English bilinguals at the Grade 3-5 levels (i.e., at

8-10 years of age) in Canada and Pakistan. Cross-language transfer effects were evident in Canada (Mirza & Gottardo, 2023). Urdu phonological awareness was negatively associated with English reading in Pakistan (Mirza & Gottardo, 2023), which may be due to the type of bilingual population selected for the study (Chang & Monaghan, 2018). Mirza and Gottardo (2023) assessed sequential bilinguals in Pakistan who were first exposed to Urdu within the home and later exposed to English within the school environment. It could be that these subtractive bilinguals (i.e., who gained proficiency in one language [English] through schooling, while losing proficiency in the other language [Urdu]) did not demonstrate sufficient Urdu oral-language and pre-reading skills for positive cross-language transfer to English reading (Cummins, 1981; Mirza & Gottardo, 2023). These prior Urdu reading studies (Mirza & Gottardo, 2023; Mirza & Gottardo, 2022; Mirza et al., 2017) briefly assessed phonological awareness skills via a 10-item word-initial, medial- and final- sound elision task (Mirza & Gottardo, 2023; Mirza & Gottardo, 2022; Mirza et al., 2017) and a 10-item word-initial sound substitution task (Mirza et al., 2017). The studies only examined phoneme-level awareness (and not onset-rime or syllable grain size levels), and did not assess children's RAN skills in relation to reading outcomes (Mirza & Gottardo, 2023; Mirza & Gottardo, 2022; Mirza et al., 2017).

The Current Study

To address the English/European-centric language bias in reading research (Blasi et al., 2022; Share, 2008), this study examines cross-language transfer of phonological processing skills for reading in simultaneous bilingual children with linguistically-distant language combinations, Urdu and English. In addition, we will examine transfer, while accounting for one source of diversity in the bilingual language experience – differences in language status and language exposure/usage contexts due to the country of assessment. We did so because differences in bilingual language profiles have been shown to influence child performance on pre-reading and reading tasks (Gottardo et al., 2021; Koverlman et al., 2008). Cross-language transfer theories also highlight the role of language experience in transfer (Linguistic Interdependence Framework [LIH]; Cummins, 1981; Contrastive-Typological Framework and Contrastive Analysis Hypothesis [CAH]; Lado, 1964; Zaretsky, 2016), hence motivating our examination of country-based language contexts (i.e., Urdu as a national/societal-language in Pakistan, compared to Urdu as a heritage-language in Canada) in the current study.

The current study comprehensively assessed phonological awareness and RAN skills using multiple subtests from the age, linguistically, and culturally-responsive Urdu Phonological Tele-Assessment Tool (U-PASS), for which we had established prior criterion-based concurrent and longitudinal predictive validity (Bhalloo & Molnar, 2023; Bhalloo & Molnar, 2024). We used the U-PASS to examine cross-language transfer effects for

phonological awareness (at the onset-rime, syllable, and phoneme grain sizes) and RAN skills in relation to reading abilities at the kindergarten - Grade 1 levels (i.e., at 5 - 7 years), when phonological assessment is crucial for early word-level reading (Hogan et al., 2005; Schuele et al., 2007). Our study assessed the two Urdu kindergarten-level phonological processing components – phonological awareness and RAN – in relation to Grade 1 English reading outcomes in Urdu-English simultaneous bilinguals (i.e., who were exposed to both Urdu and English prior to 3 years, before schooling; Patterson et al., 2002) across Pakistan and Canada. Our chosen age criteria was based on the recommended ages for reading assessment, typically from kindergarten - Grades 1-2, and the age at which children are typically exposed to smaller phoneme-level phonological grain sizes and initial word reading instruction in the school system (Hogan et al., 2005; Schuele et al., 2007). We assessed both phonological awareness and RAN skills, keeping in mind their importance in early pre-reading assessment and for successful reading development (Hogan et al., 2005; Bhalloo & Molnar, 2021).

Objectives

This longitudinal study investigates whether kindergarten-level Urdu phonological awareness and rapid automatized naming (RAN) skills, as assessed by the U-PASS tool, predict Grade-1 English word and non-word reading accuracy – after accounting for the influences of demographic

background, language-dominance profiles, and domain-general cognitive skills that have been shown to be important for reading development across languages (Pasquarella et al., 2015; Ramirez et al., 2010). To do so, we will address the following question:

1. Does Urdu phonological processing, as assessed by the U-PASS tool at the kindergarten level, longitudinally predict the future English reading accuracy skills, as assessed at the Grade 1 level, of Urdu-English simultaneous bilingual children in Experiment 1: Pakistan, with an Urdu national/societal-language context (where children are typically exposed to Urdu within the home and wider society, and formally taught to read Urdu within the school system); and in Experiment 2: Canada, with an Urdu heritage-language context (where children are typically exposed to Urdu within the home and, at times, within the context of additional heritage-language classes)?

Hypothesis

We hypothesize that kindergarten Urdu phonological processing skills will predict Grade 1 English reading, in accordance with the interactive framework for cross-language transfer of reading skills (Chung et al., 2018) and Central Processing Hypothesis (Geva & Wade-Woolley, 1998). For example, we anticipate that children who demonstrate higher Urdu phonological processing scores will also demonstrate higher English reading scores. Since the Urdu-English bilinguals in Pakistan would have received greater Urdu exposure, both informally and formally in the home

and school due to Urdu's national/societal-language status, we anticipate stronger predictions between Urdu phonological processing and English reading in Pakistan. We expect these findings due to the link between heritage-language proficiency and cross-language transfer to the societal-language (Linguistic Interdependence Framework [LIH]; Cummins, 1981; Transfer Facilitation Model; Koda, 2008). In addition, the quantity and quality of language exposure has been linked to future reading development (Chang & Monaghan, 2018; Lundberg, 2006). In comparison, we anticipate comparatively weaker predictions between Urdu phonological processing and English reading for the Canadian bilinguals due to decreased Urdu exposure in a heritage-language context where Urdu is not the dominant societal-language.

METHOD

This study is part of a larger scale longitudinal project that examined biliteracy development in Urdu-English bilinguals in Pakistan and Canada. In the current study, we present the methods and results relevant to our research question defined above.

Ethics

We have obtained ethics approval from the Social Sciences, Humanities, and Education
Research Ethics Board at the University of Toronto (RIS Human Protocol Number: 38608).

Experiment 1: Pakistan

Study Participants

Based on G*Power Analysis (Faul et al., 2009) to account for the number of variables in our statistical analyses and the inherent variability in children's reading samples, we assessed 105 Senior kindergarten-aged Urdu-English simultaneous bilinguals at timepoint 1 (i.e., at 5-6 years; at the end of Senior kindergarten). We assessed 104 children after 1 school year, at timepoint 2 (i.e., at 6-7 years; at the end of Grade 1) in Pakistan, due to attrition of one child at timepoint 2. As such, the statistical analyses for Experiment 1 include data from 104 participants in Pakistan who were assessed at both timepoints of this longitudinal study.

Eligibility

We included participants who: (i) speak Urdu as their home/heritage language and English as their school/societal language, (ii) acquired both Urdu and English prior to 3 years (i.e., were simultaneous bilinguals; Patterson, 2002), and (iii) have no reported/demonstrated history of oral-language, reading, or cognitive difficulties. Table 1 summarizes participant descriptives, including language and demographic background in Pakistan.

Table 1.

Participant Descriptives for the 104 Urdu-English Bilinguals in Pakistan. Table indicates age in months at Timepoint 1, gender, English and Urdu average age of acquisition (AoA), Timepoint 1 English and Urdu language proficiency (as indicated by percentage of language exposure and usage reported by parents), and socio-economic status (as indicated by reported maternal and paternal education levels and child school neighbourhood) for the 104 Urdu-English bilinguals in Experiment 1: Pakistan.

Country	Variable	Minimu	Maximu	Mea	Standard

		m	m	n	Deviation (SD)
Experiment 1: Urdu-English Bilinguals in Pakistan (*n* = 104)	Timepoint 1 Average Age at Assessment (in months)	57	91	74.96	7.29
	Gender, n (%)				
	Female	40 (39%)			
	Male	64 (61%)			
	Average English Age of Acquisition (in months)	0	36	20.14	14.00
	Average Urdu Age of Acquisition (in months)	0	36	4.50	7.75
	Average Timepoint 1 English Language Proficiency (%) [P]	0	60	26.10	15.99
	Average Timepoint 1 Urdu Language Proficiency (%) [P]	40	100	73.90	15.99
	Socio-Economic Status (SES) [SESPK]	1.50	4.00	2.60	0.71

Note. [P]= For average Urdu language proficiency, parents indicated language exposure (i.e., percentage heard) and usage (i.e., percentage spoken) rates; Urdu and English language proficiency rates together add up to 100%. [SESPK] = SES for Pakistan was calculated from average parental SES

(based on reported maternal and paternal education levels in Pakistan: 0 [none]; 1 [matriculation]; 2 [intermediate]; 3 [bachelors]; 4 [master's]; 4.5 [double master's]; 5 [PhD]) and average parental SES based on child school neighbourhood in Pakistan (as indicated by monthly school fees in Pakistani rupees [Rs]: 1 [< Rs 2000]; 2 [Rs 2000 - Rs 5000]; 3 [Rs 5000 - Rs 10,000]; 3.5 [Rs 10,000 - Rs 20,000]; 4 [Rs 20,000 - Rs 40,000]; 5 [Rs > 40,000]).

Recruitment

We recruited participants by collaborating with community schools and not-for-profit organizations affiliated with Icon for Child and Adult Nurturing (ICAN) in Karachi, Pakistan.

Experimental Protocol

Procedure

After completing the eligibility screening form, parents then completed consent and two child and parental background questionnaires at both timepoint 1 and timepoint 2. The three parental forms took parents approximately 10-15 minutes to complete. Along with the parental consent forms, testers obtained verbal assent from each child and verified video and sound quality, prior to conducting each online assessment session. In line with tele-assessment guidelines (Wood et al., 2021), our testing team used Zoom to assess each child on their non-linguistic cognitive skills and Urdu phonological processing skills at timepoint 1, and English word/non-word reading accuracy skills at timepoint 2. Each child completed the experimental measures within 1-2 hours, depending on their attention span, need for breaks, and response rate. Each session was 1 hour, and all sessions were completed within a week. All testers completed training and testing simulations prior to conducting assessments. The Urdu phonological

processing measure was administered by Urdu native speakers. The testers did not follow standardized basal and stopping rules for Urdu and English oral language and reading tests. As the English tests have been standardized for monolingual English-speaking populations in North-American contexts, we cannot compare the Urdu-English bilinguals in this cross-country study to English monolingual performance norms. We concluded subtest testing when a child did not respond to more than 75% of test items on a page; the tester then proceeded with the subsequent subtest. Testers also noted both non-responses and other incorrect responses on the experimental measures by the participants. See Supplementary Figure S1 for measures at timepoint 1 and timepoint 2 of this longitudinal study.

Measures

Parent-Completed Questionnaires.

Consent Form. See Supplementary Table S2 for the consent form.

Child Language Background Questionnaire. The Child Language Experience and Proficiency Questionnaire ([LEAP-Q]; Marian et al., 2007a; Marian et al., 2007b) is a parental report of child language background which is used by researchers across multiple disciplines, including speech-language pathology, linguistics, education, psychology and neuroscience. We adapted and used the LEAP-Q to collect parental reports of age at assessment (in months), gender, age of acquisition (AoA), and language proficiency/dominance (i.e., percentage of exposure and usage) across the

Urdu-English bilingual children's two languages. See Supplementary Table S2 for the child language background questionnaire.

Parental Demographic Questionnaire. This demographic self-report questionnaire collects parental demographic, language background and socio-economic status (SES) information. We asked parents to report country-specific indicators of socio-economic status (SES), due to potential influences on child pre-reading and reading outcomes – beyond bilingual experience (Meir & Armon-Lotem, 2017; Wood et al., 2018). These country-specific SES indicators include paternal and maternal education levels, occupation, child school tuition rates (for Pakistan), and child school neighbourhood (for Canada). Our questionnaire is similar to questionnaires used by other biliteracy studies (e.g., Mirza et al., 2017). See Supplementary Table S2 for the parental language/demographic background questionnaire.

Experimental Measures.

Domain-General/Non-Linguistic Cognitive Measure. The Matrix Analogies Test-Expanded Form ([MAT-EF]; Naglieri & Insko, 1986) is a language general measure of non-verbal reasoning that is based on visually-presented pictures and patterns. The MAT-EF includes four subtests, each with 16 items: pattern completion, reasoning by analogy, serial reasoning, and spatial visualization.

Urdu Phonological Processing Measure. The open-access Urdu Phonological Tele-Assessment (U-PASS) tool assesses children's ability to

recognize, segment, and manipulate presented spoken sound segments. The age-, linguistically-, and culturally-appropriate U-PASS tool has prior demonstrated within-language criterion-based concurrent validity (Bhalloo & Molnar, 2023). In this cross-language transfer study, children were tested and assessed on the phonological awareness (compound-level and phoneme-level sound elision, sound matching, compound-level, syllable-level, and phoneme-level word and non-word blending subtests) and letter and digit rapid automatized naming (RAN) components of the U-PASS tool. The phonological awareness and RAN components were selected due to their clinical relevance and common use by SLPs and educators for school-aged children. The letter and digit RAN subtests were included due to their relevance to word reading (Hornung et al., 2017). See Supplementary Table S2 for the U-PASS tool's visual and audio-based stimuli and scoring form.

English Word/Non-Word Reading Accuracy Measures. We tested children's word/non-word reading accuracy skills via two subtests from the Woodcock Reading Mastery Test ([WRMT-III]; Woodcock, 2011). Children were presented with 76 English words (Word Identification subtest) and 44 English non-words (Word Attack subtest), and were scored based on the total number of correct responses. The WRMT-III (Woodcock, 2011) is a norm-referenced standardized measure of word-reading in English. The WRMT-III has an established convergent validity ($r = 0.9$, $p<0.01$) and internal reliability ranging from $r = .91$ to $r = .98$ (Pae et al., 2005). We did not include English reading fluency measures due to English's

comparatively opaque orthography. SLPs and educators in North America typically only assess children's English word-level reading accuracy at the Grade 1 level, due to its orthographic depth (i.e., the degree of 1:1 consistency between symbol [i.e., grapheme] – sound [i.e., phoneme] mappings in alphabetic orthographies; these are relatively inconsistent in opaque orthographies compared to transparent orthographies). English word reading fluency is typically mastered and assessed at higher grade levels, such as from Grades 3 – 4 and beyond. This is due to inconsistent grapheme - phoneme correspondences (GPCs) in the opaque English orthography, which results in young readers developing phonological decoding (i.e., the ability to recognize and combine individual graphemes, associated with phonemes, to decode and read a written word) and rapid word recognition skills at a later age. In comparison, readers in transparent orthographies, such as Urdu, become accurate and fluent readers at an earlier age, such as at the Grade 1 level, due to consistent GPCs (Borleffs et al., 2019).

Statistical Methods

This longitudinal study examines cross-language transfer effects for Urdu phonological processing, specifically phonological awareness and RAN components using the U-PASS tool, in relation to English word and non-word reading accuracy measures. To investigate this, we conducted hierarchical linear regression analyses based on an enter method for variable selection, and a specified statistical significance of $p \leq 0.05$

(Hosmer et al., 2013; Lemeshow et al., 2011). We ensured that the regression analyses met the assumptions of normality, homoscedasticity, multicollinearity, outliers, and independence. We identified outliers, but retained them in our analysis as they did not significantly affect our results. In our hierarchical linear regression analyses, we used Cohen's local f^2 as an indicator of effect size specific to our main predictor variable of interest (i.e., in the final Step 4: Urdu phonological awareness, or Urdu RAN; Selya et al., 2012). We categorized effect sizes in line with Cohen's (1988) guidelines: $f^2 \geq 0.02$ (as small effect size), $f^2 \geq 0.15$ (as medium effect size), and $f^2 \geq 0.35$ (as large effect size). *Note*. We acknowledge that the interpretation of effect sizes is contextual; however, prior studies in this field have not typically reported effect sizes for hierarchical linear regressions, therefore limiting comparison. It is also important to note that 'small' effect sizes can be 'large' in real-world contexts, such as assessment and cross-language transfer studies with linguistically-distant bilingual language combinations (e.g., Carey et al., 2023).

Predictor Variables

The predictor variables included in the hierarchical linear regression are: age (in months), gender, socio-economic status (Step 1), domain-general cognitive skills (Step 2), Timepoint 1 English proficiency (Step 3), and the target predictor variable Urdu phonological processing as measured by the U-PASS (i.e., phonological awareness and letter, digit RAN subtests; Step 4). The control variables in Steps 1-3 were determined based

on prior similar studies (see, Bhalloo & Molnar, 2021; Mirza et al., 2017; see hierarchical linear regression tables below for Steps 1 - 4). This allowed us to determine if kindergarten Urdu phonological awareness and RAN scores contribute unique variance to Grade 1 English reading accuracy, above demographic and language dominance factors included in prior cross-language studies (see Durgunoğlu, 1993; Lafrance & Gottardo, 2005; Ramirez et al., 2010; Deacon et al., 2013; Pasquarella et al., 2015).

Dependent Variables

The predictor variables in Steps 1 - 4 were analyzed in relation to two dependent variables: (1) English word reading accuracy and (2) English non-word reading accuracy (see hierarchical linear regression tables below for Steps 1 - 4). We did so to determine if kindergarten-level Urdu phonological processing contributes unique variance to Grade 1 English reading, above the influence of demographic and language dominance factors.

RESULTS

Descriptive Statistics and Correlations for Measures

Table 2 summarizes the descriptive statistics, including mean, range, and standard deviation, for the non-linguistic cognitive, Urdu phonological awareness, Urdu RAN, and English reading measures included in our analyses in Pakistan.

Table 2.

Descriptive Statistics for Experimental Measures in Pakistan. Table indicates descriptive statistics for the non-linguistic cognitive (Matrix

Analogies Test-Expanded Form [MAT-EF]), Urdu phonological awareness (U-PASS), Urdu letter and digit rapid automatized naming (RAN; U-PASS), and English word and non-word reading accuracy measures (Woodcock Reading Mastery Test [WRMT-III]; Test of Word Reading Efficiency [TOWRE-2]) for the 104 Urdu-English bilinguals in Pakistan.

Country	Experimental Measure	Minimum	Maximum	Mean	Standard Deviation (SD)
Experiment 1: Urdu-English Bilinguals in Pakistan (*n* = 104)	Non-Linguistic Cognitive	9	58	31.56	12.04
	Urdu Phonological Awareness (U-PASS tool)	47	136	101.34	21.14
	Urdu Letter and Digit Rapid Automatized Naming (RAN; U-PASS tool)	0	122.21	59.27	26.65
	English Word Reading Accuracy	10	76	48.87	14.10
	English Non-Word Reading Accuracy	4	43	24.42	9.26

In Supplementary Table S3, we present correlations for the non-linguistic cognitive, Urdu phonological awareness, Urdu RAN, and English reading accuracy experimental measures included in our statistical analyses in Pakistan. In the correlation matrix, we found moderate-strong level correlations between Timepoint 1 Urdu phonological awareness and Timepoint 2 English word and non-word reading accuracy measures in Pakistan (ranging from $r = 0.43$ to $r = 0.47$). Low-level correlations were evident for the Timepoint 1 Urdu RAN and the Timepoint 2 English word and non-word reading accuracy measures (ranging from $r = 0.10$ to $r = 0.15$).

Cross-Language Transfer Effects for Urdu Phonological Processing and English Reading in Pakistan

We present hierarchical linear regression analyses separate by country, as we seek to investigate cross-language transfer effects for kindergarten-level Urdu phonological processing in relation to the future Grade 1 English reading accuracy skills of Urdu-English bilingual children, in both a national/societal-language (i.e., Pakistan; Experiment 1) and heritage-language context (i.e., Canada; Experiment 2). As well, the interaction terms for Urdu phonological awareness and RAN were significant across most reading measures. Supplementary tables S4 – S7 indicate the interaction terms for Urdu phonological awareness and RAN in relation to reading for Pakistan and Canada. Specifically, we investigated cross-language transfer effects for the Urdu phonological awareness and

RAN components of the U-PASS tool across the English word reading accuracy and non-word reading accuracy outcome measures. We present these analyses for Pakistan, below.

Urdu Phonological Awareness and English Word Reading Accuracy

Supplementary Table S8 presents the hierarchical linear regression for Timepoint 1 Urdu phonological awareness, with Timepoint 2 English word reading accuracy as the outcome variable (see Supplementary Figure S9, Experiment 1 for scatterplot). The main purpose of this regression was to examine whether Urdu phonological awareness longitudinally predicts English word reading accuracy in Pakistan. The predictor variable of interest (entered in the last step), Urdu phonological awareness, accounted for 3% of the variance in English word reading accuracy (F(1, 97] = 5.92, p < 0.05; Cohen's local f^2 = 0.06). The final beta weights indicate that only age at assessment (t = 2.10, p <0.05), SES (t = 2.09, p <0.05), non-linguistic cognitive skills (t = 4.20, p <0.001), and Urdu phonological awareness (t = 2.43, p <0.05) were significant independent predictors of English word reading accuracy.

Urdu Phonological Awareness and English Non-Word Reading Accuracy

Supplementary Table S10 indicates the hierarchical linear regression for Timepoint 1 Urdu phonological awareness, with Timepoint 2 English word non-reading accuracy as the outcome variable (see Supplementary Figure S11, Experiment 1 for scatterplot). The purpose of this regression

was to examine whether Urdu phonological awareness longitudinally predicts English non-word reading accuracy in Pakistan. The predictor variable of interest (entered in step 4), Urdu phonological awareness, accounted for 6% of the variance in English non-word reading accuracy (F (1, 97] = 9.70, $p < 0.01$; Cohen's local $f^2 = 0.10$). As revealed by the final beta weight, only non-linguistic cognitive skills ($t = 3.26$, $p < 0.01$) and Urdu phonological awareness ($t = 3.11$, $p < 0.01$) were unique predictors of English non-word reading accuracy.

Urdu RAN and English Word Reading Accuracy

As shown in Supplementary Table S12, we present the hierarchical linear regression for Timepoint 1 Urdu RAN in relation to Timepoint 2 English word reading accuracy as the outcome variable (see Supplementary Figure S13, Experiment 1 for associated scatterplot). The primary purpose of this regression was to examine whether Urdu RAN longitudinally predicts English word reading accuracy in Pakistan. Urdu RAN accounted for 5% of the variance in English word reading accuracy (F (1, 43] = 8.92, $p < 0.01$; Cohen's local $f^2 = 0.09$). The final beta weights indicate that only age ($t = 3.39$, $p < 0.01$), the non-linguistic cognitive measure ($t = 6.07$, $p < 0.001$), Timepoint 1 English Language Proficiency ($t = 2.26$, $p < 0.05$), and Urdu RAN ($t = 2.98$, $p < 0.01$) were unique predictors of English word reading accuracy.

Urdu RAN and English Non-Word Reading Accuracy

Supplementary Table S14 presents the hierarchical linear regression for Timepoint 1 Urdu RAN, with Timepoint 2 English non-word reading accuracy as the outcome variable (see Supplementary Figure S15, Experiment 1 for scatterplot). The main purpose of this regression was to examine whether Urdu RAN longitudinally predicts English non-word reading accuracy in Pakistan. The predictor variable of interest (entered in the fourth step), Urdu RAN, accounted for 3% of the variance in English non-word reading accuracy (F(1, 97] = 5.00, p < 0.05; Cohen's local f^2 = 0.05). The final beta weights indicate that only age (t = 2.85, p <0.01), non-linguistic cognitive skills (t = 5.03, p <0.001), Timepoint 1 English Language Proficiency (t = 2.03, p <0.05), and Urdu RAN (t = 2.23, p <0.05) uniquely predicted English non-word reading accuracy.

Experiment 2: Canada

METHODS

In the upcoming sections, we present the methods and results for Experiment 2: Canada. Experiment 2's Methods followed the same steps as Experiment 1, which are described above.

Study Participants

Similar to prior Urdu bilingual studies (Mirza & Gottardo, 2023; Mirza & Gottardo, 2022; Mirza et al., 2017), we assessed 53 Senior kindergarten-aged Urdu-English simultaneous bilinguals on their pre-reading skills at timepoint 1 (i.e., at 5-6 years; at the end of Senior kindergarten) and 50 children at timepoint 2 (i.e., at 6-7 years; at the end of Grade 1) in Canada.

We excluded data from three Canadian participants due to attrition at timepoint 2. As such, the statistical analyses for Experiment 2 include data from 50 participants in Canada who were assessed at both timepoints of this longitudinal study. Table 3 below summarizes the participant descriptives, including language and demographic background, for Experiment 2 (i.e., Canada).

Table 3.

Participant Descriptives for the 50 Urdu-English Bilinguals in Canada. Table indicates age in months at Timepoint 1, gender, English and Urdu average age of acquisition (AoA), Timepoint 1 English and Urdu language proficiency (as indicated by percentage of language exposure and usage reported by parents), and socio-economic status (as indicated by reported maternal and paternal education levels and child school neighbourhood) for the 50 Urdu-English bilinguals in Experiment 2: Canada.

Country	Variable	Minimum	Maximum	Mean	Standard Deviation (SD)
Experiment 2: Urdu-English Bilinguals in Canada (*n* = 50)	Timepoint 1 Average Age at Assessment (in months)	55	89	70.72	8.270
	Gender, n (%)				
	Female	26 (52%)			
	Male	24 (48%)			
	Average English Age of Acquisition (in months)	0	36	11.94	15.66

Average Urdu Age of Acquisition (in months)	0	36	1.13	5.89
Average Timepoint 1 English Language Proficiency (%) [P]	10	85	48.49	20.48
Average Timepoint 1 Urdu Language Proficiency (%) [P]	15	100	51.51	20.48
Socio-Economic Status (SES) [SESCAN]	1.50	3.75	2.94	0.45

Note. [P]= For average Urdu language proficiency, parents indicated language exposure (i.e., percentage heard) and usage (i.e., percentage spoken) rates; Urdu and English language proficiency rates together add up to 100%. [SESCAN] = SES for Canada was calculated from average parental SES (based on reported maternal and paternal education levels in Canada: 0 [none]; 1 [high school]; 2 [college]; 3 [bachelors]; 4 [master's]; 4.5 [double master's]; 5 [PhD]) and average parental SES based on child school neighbourhood in Canada (as indicated by mean household income in Canadian dollars [$]: 1 [< $30,000]; 2 [$30,000 - $60,000]; 3 [$60,000 - $90,000]; 3.5 [$90,000 - 200,000]; 4 [$200,000 - $300,000]; 5 [> $300,000; Statistics Canada, 2011a; Townfolio, 2017]).

Recruitment

Participants were recruited via Urdu-related social media platforms and community organizations.

Eligibility

See Experiment 1 for Eligibility criteria.

Experimental Protocol

See Experiment 1 for Procedure and Measures, including parent-completed questionnaires and experimental measures.

Statistical Methods

We ensured that the hierarchical linear regression analyses met regression assumptions, and used Cohen's local f^2 as an indicator of effect size in our hierarchical linear regression analyses. Identified outliers were retained in our analysis as they did not significantly affect our results. See Experiment 1 for additional information regarding Statistical Methods, Predictor Variables, and Dependent Variables.

RESULTS

Here, we present cross-language transfer effects for kindergarten-level Urdu phonological processing in relation to Grade 1 English word/non-word reading accuracy in Urdu-English bilinguals in Experiment 2: Canada, where Urdu has heritage-language status.

Descriptive Statistics and Correlations for Measures

Table 4 summarizes the descriptive statistics, including mean, range, and standard deviation, for the non-linguistic cognitive, Urdu phonological awareness, Urdu RAN, and English reading measures included in our statistical analyses in Canada.

Table 4.

Descriptive Statistics for Experimental Measures in Canada. Table indicates descriptive statistics for the non-linguistic cognitive (Matrix Analogies Test-Expanded Form [MAT-EF]), Urdu phonological awareness (U-PASS), Urdu letter and digit rapid automatized naming (RAN; U-PASS), and English word and non-word reading accuracy measures (Woodcock Reading Mastery Test [WRMT-III]; Test of Word Reading Efficiency [TOWRE-2]) for the 50 Urdu-English bilinguals in Experiment 2: Canada.

Country	Experimental Measure	Minimum	Maximum	Mean	Standard Deviation (SD)
Experiment 2: Urdu-English Bilinguals in Canada (*n* = 50)	Non-Linguistic Cognitive	11	46	28.96	9.43
	Urdu Phonological Awareness (U-PASS tool)	51	118	88.98	16.62
	Urdu Letter and Digit Rapid Automatized Naming (RAN; U-PASS tool)	0	89.34	28.28	17.44
	English Word Reading Accuracy	6	72	55.26	15.32
	English Non-Word Reading Accuracy	2	41	24.52	9.70

In Supplementary Table S16, we present correlations for the non-linguistic cognitive, Urdu phonological awareness, Urdu RAN, and English reading accuracy experimental measures included in our statistical analyses

in Canada. Our correlation matrix showed moderate-strong level correlations between kindergarten-level Urdu phonological awareness and Grade 1 English word and non-word reading accuracy measures (ranging from $r = 0.51$ to r = 0.60). In Canada, there were low-level correlations for the kindergarten-level Urdu RAN measures and the Grade 1 English word reading accuracy measure ($r = 0.27$). Urdu RAN was not significantly correlated with English non-word reading accuracy in Canada.

Cross-Language Transfer Effects for Urdu Phonological Processing and English Reading in Canada

We present our cross-language transfer analyses for Canada below.

Urdu Phonological Awareness and English Word Reading Accuracy

Supplementary Table S17 presents the hierarchical linear regression for Timepoint 1 Urdu phonological awareness, with Timepoint 2 English word reading accuracy as the outcome variable (see Supplementary Figure S9, Experiment 2 for scatterplot). The main purpose of this regression was to examine whether Urdu phonological awareness longitudinally predicts English word reading accuracy in Canada. The predictor variable of interest (entered in the last step), Urdu phonological awareness, accounted for 13% of the variance in English word reading accuracy ($F(1, 43] = 8.73$, $p < 0.01$; Cohen's local $f^2 = 0.20$). The final beta weights indicate that only Urdu phonological awareness ($t = 2.95$, $p < 0.01$) emerged as an independent predictor of English word reading accuracy.

Urdu Phonological Awareness and English Non-Word Reading Accuracy.

Supplementary Table S18 indicates the hierarchical linear regression for Timepoint 1 Urdu phonological awareness, with Timepoint 2 English word non-reading accuracy as the outcome variable (see Supplementary Figure S11, Experiment 2 for scatterplot). The purpose of this regression was to examine whether Urdu phonological awareness longitudinally predicts English non-word reading accuracy in Canada. The predictor variable of interest (entered in step 4), Urdu phonological awareness, accounted for 18% of the variance in English non-word reading accuracy (F (1, 43] = 14.17, $p < 0.001$; Cohen's local $f^2 = 0.32$). As revealed by the final beta weight, only Urdu phonological awareness ($t = 3.76$, $p < 0.001$) uniquely predicted English non-word reading accuracy.

Urdu RAN and English Word Reading Accuracy

As shown in Supplementary Table S19, we present the hierarchical linear regression for Timepoint 1 Urdu RAN in relation to Timepoint 2 English word reading accuracy as the outcome variable (see Supplementary Figure S13, Experiment 2 for associated scatterplot). The primary purpose of this regression was to examine whether Urdu RAN longitudinally predicts English word reading accuracy in Canada. Urdu RAN accounted for 6% of the variance in English word reading accuracy (F (1, 43] = 4.09, $p < 0.05$; Cohen's local $f^2 = 0.09$). The final beta weights indicate that only Urdu RAN ($t = 2.02$, $p < 0.05$) uniquely predicted English word reading accuracy.

Urdu RAN and English Non-Word Reading Accuracy

Supplementary Table S20 presents the hierarchical linear regression for Timepoint 1 Urdu RAN, with Timepoint 2 English non-word reading accuracy as the outcome variable (see Supplementary Figure S15, Experiment 2 for scatterplot). The main purpose of this regression was to examine whether Urdu RAN longitudinally predicts English non-word reading accuracy in Canada. Urdu RAN was not a significant predictor of English non-word reading accuracy. The final beta weights indicate that the non-linguistic cognitive measure ($t = 2.66$, $p < 0.05$) was the only independent predictor of English non-word reading accuracy.

DISCUSSION

Our study is amongst the few studies to longitudinally examine cross-language transfer effects for Indo-Aryan languages, such as Urdu (Mirza & Gottardo, 2023; Mirza & Gottardo, 2022; Mirza et al., 2017). We tested phonological processing skills – particularly, phonological awareness and RAN – and English word-level reading across two diverse country contexts. In the upcoming sections, we also discuss the clinical and research implications of our cross-language transfer findings for Urdu-English bilingual children in both Pakistan and Canada, as well as for bilingual readers of English who also speak a heritage-language that is linguistically related to Urdu globally.

Cross-Language Transfer Effects: Common Findings Across Pakistan and Canada

Urdu Phonological Awareness and English Reading

Across Canada and Pakistan, Urdu phonological awareness consistently contributed to English word and non-word reading accuracy. In general, our cross-language transfer findings are in line with prior studies investigating the relationship between meta-linguistic skills and reading ability in linguistically-distant languages (e.g., Melby-Lervåg & Lervåg, 2011; Schwartz et al., 2007). Across our correlation matrix and hierarchical linear regression analyses for Pakistan and Canada, we found stronger predictions between Urdu phonological awareness and English non-word reading, as compared to the word reading measures in both Pakistan (word reading accuracy: 3% variance; non-word reading accuracy: 6% variance) and Canada (word reading accuracy: 13% variance; non-word reading accuracy: 18% variance). These findings emphasize the importance of phonological awareness for forming grapheme - phoneme correspondences (GPCs) and using phonological decoding strategies to identify/sound out individual graphemes and blend together their associated phonemes to read unfamiliar non-words (Swank & Catts, 1994; Hogan et al., 2005; Powell & Atkinson, 2021). Comparatively, children will usually utilize a combination of phonological decoding (which involves phonological awareness) and sight-word (which primarily involves processing speed and memory) reading strategies to read words, depending on their reading experience as well as lexical familiarity and consolidation of familiar words within long-term memory (Ehri, 2001; Ehri, 2005; Ehri, 2013; Miles & Ehri, 2019).

Overall, our analyses demonstrated cross-language transfer of Urdu phonological awareness for English word and non-word reading accuracy in Urdu-English simultaneous bilinguals across two country contexts. Bilinguals are a heterogeneous group, and are commonly categorized in terms of their age of acquisition (AoA), language proficiency, and the duration, quality, and interactional contexts/environments for language exposure and usage. In this study, we accounted for AoA and language proficiency across both languages by assessing simultaneous bilinguals (i.e., with AoA between 0 - 3 years), while examining transfer in one source of variance in the bilingual language experience: two countries, with differences in Urdu-language status and exposure/usage contexts. By doing so, we enhanced the generalizability of our findings to bilinguals in diverse linguistic contexts.

Urdu Letter & Digit RAN and English Reading

Our analyses also examined the longitudinal relationship between Urdu RAN and English word and non-word reading accuracy. We included letter and digit RAN due to their links to word reading, in terms of the retrieval of print-related stimuli (Hornung et al., 2017). Across our correlation matrix and hierarchical linear regressions in the two countries, we generally found stronger associations between Urdu phonological awareness and English reading accuracy, compared to RAN. In Pakistan, Urdu RAN contributed to 5% and 6% of the variance in English word and non-word reading accuracy (ranging from $r = 0.10$ to $r = 0.15$, $p < 0.05$),

with RAN contributing to 3% of the variance in English word reading accuracy in Canada ($r = 0.27$, $p < 0.05$). RAN was not a significant predictor of non-word reading accuracy in Canada (see Country-Specific Findings section below for further discussion).

RAN supports retrieval of phonological and orthographic information stored in long-term memory, such as acquired symbol-sound mappings, word units and whole words, during later fluent word recognition (Catts, 2018; Papadopoulos et al., 2016). Fluent word recognition, which relies on whole-word reading strategies, involves a speed-of-processing component similar to RAN. This language-general cognitive process forms one of the hypothesized theoretical bases of the RAN-reading fluency relationship, and may be the reason why RAN was not as strongly associated with the reading accuracy measures in this study – as compared to phonological awareness (Georgiou et al., 2016; Papadopoulos et al., 2016). In general, we found that phonological awareness was a more reliable predictor of early word/non-word reading accuracy, which is likely due to the task requiring awareness of phonological units and effortful decoding of individual GPCs. RAN did not seem to be a sensitive indicator of word and non-word reading accuracy in this cross-language study. Our findings also reflect prior studies which highlight that RAN – while a contributor to reading accuracy – is more strongly associated with reading fluency measures, even when examined in relation to reading outcomes in the same language (Landerl et al., 2019).

Country-Specific Findings: Cross-Language Transfer of RAN

Pakistan

Urdu RAN significantly predicted English word and non-word reading accuracy in Pakistan. Children in Pakistan are typically exposed to print and receive Urdu and English reading instruction at the kindergarten level (Government of Pakistan, 2021; Government of Pakistan, 2022). As such, the Urdu-English bilinguals in Pakistan may have acquired GPCs and phonological decoding strategies at an earlier age and were using comparatively more whole-word reading strategies, with a speed-of-processing component similar to that used in RAN tasks, to recognize and retrieve familiar whole words and word segments during the reading tasks (Ehri, 2017).

Canada

The use of phonological decoding, as compared to whole-word, reading strategies at the Grade 1 level may explain the low-level and non-significant relationships between RAN and the reading accuracy measures in Canada. Children in Canada typically receive consistent reading instruction at the Grade 1 level across schools (Ontario Curriculum and Resources, 2023). Due to this later age at first reading exposure, the Canadian bilinguals may still be forming GPCs and had to decode each individual grapheme to sound out the formed word during reading, instead of using the whole-word retrieval strategies that also underlie RAN tasks. The low-level and non-significant RAN-reading relationship patterns for the Canadian bilinguals could also be due to power and sample size limitations,

as our Pakistani sample (n = 104) was twice the size of our Canadian sample (n = 50), in addition to differences in phonics-based reading instruction across the two countries (Government of Pakistan, 2021; Government of Pakistan, 2022; Ontario Curriculum and Resources, 2023).

Country Differences

While the main purpose of this study was to investigate cross-language transfer between Urdu phonological processing and English reading in two countries, we also conducted preliminary examination of country-level differences. In our hierarchical analysis for phonological awareness, phonological awareness emerged as the only unique predictor of word and non-word reading accuracy for the Canadian bilinguals. There were also stronger predictions between Urdu phonological awareness and reading accuracy skills in Canada (word reading accuracy: 13% variance; non-word reading accuracy: 18% variance), as compared to Pakistan (word reading accuracy: 3% variance; non-word reading accuracy: 6% variance). The cross-country predictive strength differences in our hierarchical linear regressions may potentially be due to differences in language status and exposure/usage rates across the two contexts.

Given that heritage-language proficiency influences cross-language transfer to the societal-language (Linguistic Interdependence Framework [LIH]; Cummins, 1981; Transfer Facilitation Model; Koda, 2008), we expected the opposite pattern in line with our hypothesis: Stronger predictions between Urdu phonological processing and English reading in

Pakistan. This is because the quantity and quality of language exposure has been linked to future reading development (Chang & Monaghan, 2018; Lundberg, 2006). The Urdu-English bilinguals in both Canada and Pakistan received English schooling instruction. However, parents reported greater mean Urdu language exposure and usage within the home and school environments in Pakistan (Urdu proficiency: 73.90%; English proficiency: 26.10) compared to Canada (Urdu proficiency: 51.51%; English proficiency: 48.49), thereby reflecting Urdu's status as the national/societal language in Pakistan. In addition, the Urdu-English bilinguals in Pakistan demonstrated higher mean scores on the Urdu phonological awareness (Pakistan: 101.34; Canada: 88.98) and RAN (Pakistan: 59.27; Canada: 28.28) measures.

We also explored whether English language proficiency and reading abilities contributed to these cross-country predictive strength differences. It could be that the higher parent-reported mean English usage and exposure rates in Canada (Pakistan: 26.10%; Canada: 48.49%) influenced English reading abilities, and mediated the comparatively stronger predictive relationship between Urdu phonological processing and English reading skills in Canada. However, our t-tests for country differences in English word and non-word reading accuracy were not significant, and children demonstrated marginal score differences between Pakistan and Canada (Word Reading Accuracy: Pakistan: 48.87; Canada: 55.26; Non-Word Reading Accuracy: Pakistan: 24.42; Canada: 24.52). We could not

further explore the basis of the demonstrated cross-country differences due to sample size differences across the two countries.

Clinical and Research Implications

Our cross-language transfer findings highlight how the heritage-language can support development of reading skills in the educational/societal language of bilingual children. Bilingual children's heritage-language pre-reading skills were indicative of their societal-language reading skills, as demonstrated by our cross-language transfer findings with Urdu phonological processing in relation to English reading. Similarly, in other studies, kindergarten-level phonological processing skills have been shown to transfer and are indicative of future Grade 1 word-reading development across languages (Bhalloo & Molnar, 2021; Melby-Lervåg & Lervåg, 2011; Schwartz et al., 2007). As such, speech-language pathologists and educators can use heritage-language reading precursor assessment tools, such as our Urdu Phonological Tele-Assessment (U-PASS) tool, to examine and assess future reading abilities in the societal-language. Clinicians can identify and support bilingual children's future reading skills in the language of education (i.e., English), via established heritage-language phonological processing skills.

For simultaneous bilinguals, with similar age of acquisition (AoA) and near-equal proficiency, linguistically-appropriate tools enable comprehensive assessment of reading milestones across the two languages. Our U-PASS tool (Bhalloo & Molnar, 2023) has the potential to

enable clinicians to screen for and mitigate future reading and resulting academic difficulties in the language of education (i.e., English), via phonological processing skills in the dominant heritage-language — without English language proficiency confounds. While our study demonstrated cross-language transfer effects for simultaneous Urdu-English bilinguals with near-equal age of acquisition and proficiency in both languages, we also anticipate generalizability of our cross-language transfer findings to sequential bilinguals and second language learners with greater Urdu-language dominance. We expect these findings in line with other studies that have demonstrated cross-language transfer of reading skills in children with diverse language dominance profiles (Chen et al., 2010; Durgunoğlu, 1993; Chung et al., 2018).

For sequential bilingual children and second language learners with comparatively less proficiency in the language of education (which is typically English), heritage-language phonological assessment tools, such as the U-PASS tool, may be a reliable alternative to delaying pre-reading assessment until sufficient English proficiency has been gained for assessment purposes. Due to their limited English proficiency, these bilingual children will benefit from cross-language assessments that use the dominant heritage-language to identify and support their future English reading abilities. By examining Urdu phonological processing skills, SLPs can facilitate early support of English reading skills in children with limited English language proficiency, who are unable to otherwise access early pre-

reading assessment and, in turn, intervention. Our findings are also relevant to emerging readers who are developing their English reading skills, and can speak a heritage-language phonologically or orthographically related to Urdu, such as Arabic and Persian. Similar to Urdu, these languages are commonly spoken globally (Eberhard et al., 2021) – but under-investigated in speech-language and reading research.

Limitations

While our sample size is in line with biliteracy studies (O'Brien at al., 2018; Mirza et al., 2017), sample size differences emerged across Pakistan and Canada as a result of voluntary sampling methods. The larger sample size for Urdu-English bilinguals in Pakistan is representative of Urdu's status as a national/societal language, which facilitated participant recruitment. Urdu, although in the top-10 most spoken heritage-languages, is a minoritized language in Canada (Statistics Canada, 2011b; Statistics Canada, 2016). Another sample-related limitation is that our eligibility criteria included Urdu-English simultaneous bilinguals from mid-high socio-economic status (SES) background across Canada and Pakistan. While this can limit the current cross-language transfer study's generalizability, we had to consider existing structural inequities such as that access to reliable internet and English-medium schools is linked to SES in Pakistan. However, while a limitation, this resulted in our participants having generally similar demographic and language backgrounds across the countries of assessment. Other limitations include the length of assessment and

increased distraction for young children engaging in tele-assessments, for which we ensured multiple short sessions and breaks.

Future Directions

By examining cross-language transfer in two country contexts with differences in Urdu-language status and interactional (i.e., exposure and usage) contexts, this study investigated one source of heterogeneity in the bilingual language experience. To examine cross-language transfer across diverse linguistic contexts, our future research aims to assess diverse Urdu-speaking language populations across socio-economic status, language dominance profiles (as indicated by AoA and language proficiency), and demographic backgrounds. Some accessibility strategies include facilitating access to internet vouchers and transport with community centers with Wi-Fi access in country contexts with technological limitations. This will also allow us to examine cross-language transfer effects for Urdu phonological processing in relation to other societal languages beyond English and in other national/societal and heritage-language contexts. Extending this study to diverse Urdu-language country contexts, such as Fiji and the Middle-East, will enable us to compare cross-language transfer effects for Urdu phonological processing in relation to reading in both linguistically-distant languages such as English and linguistically-close languages such as Arabic and Persian.

To comprehensively investigate contributions of phonological processing components across reading outcomes, our future directions include examining longitudinal cross-language transfer effects for phonological awareness and RAN in relation to word/non-word reading accuracy and fluency measures across both the heritage and societal languages. While examining reciprocal cross-language transfer effects (i.e., between English phonological processing and Urdu reading) was beyond our current study's scope, we will examine transfer between both heritage-language and societal-language pre-reading and reading skills in a future study. As well, including fluency measures will allow us to examine the differential age-related contributions of the two phonological processing components based on the type of assessed reading outcome measure.

We did not include reading fluency measures in the current study, as we only assessed English reading ability. SLPs and educators commonly only assess reading accuracy in English at the Grade 1 level, with fluency being assessed at the Grade 2 - 3 levels. This is due to the language's opaque orthography which results in acquisition of GPCs and, in turn, accurate and fluent reading at a later age than readers in transparent orthographies (Álvarez-Cañizo et al., 2015; Borleffs et al., 2019). Our future study will examine reciprocal cross-language effects of phonological awareness and RAN influences on word and non-word reading accuracy and fluency across multiple grade levels, to allow for a more comprehensive examination. This is because RAN may play a comparatively greater role in

facilitating reading abilities as children become experienced and fluent readers at higher grade levels (Ehri, 2017).

Conclusion

Our study contributes to research in Urdu, an under-investigated yet commonly spoken language. Our cross-language transfer findings highlight the importance of the heritage-language (i.e., Urdu) for facilitating access to pre-reading assessment in typically-developing Urdu-speaking bilingual children, and promoting reading development in the societal language — thereby reducing assessment wait times for children who cannot be assessed in the societal/educational language (i.e., English). Overall, our study contributes to linguistic diversity in reading research and has clinical implications for promoting equitable access to pre-reading assessment for all children – regardless of language proficiency and background. A future study will examine the clinical implications of cross-language transfer in children identified as at-risk for reading difficulties.

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