Reading and Writing (2019) 32:839–871
https://doi.org/10.1007/s11145-018-9889-7

Cross-language transfer of reading skills: an empirical investigation of bidirectionality and the influence of instructional environments

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Published online: 1 August 2018

Abstract

The linguistic interdependence hypothesis (Cummins, 1979, 2000) states that children's second-language (L2) proficiency is, to some extent, a function of their first-language (L1) competence. Previous studies have examined this hypothesis with focus on a unidirectional relation from L1 to L2. In the present study, we examined *bidirectional* influences of literacy skills in multilingual contexts, and whether the nature of relations varied as a function of literacy instruction environment. To do so, we used longitudinal data from a randomized controlled trial of a literacy intervention for children in Grades 1 and 2, learning to read in Kiswahili and English, two official languages in Kenya. Children in the treatment condition received explicit and systematic instruction on literacy (e.g., phonological awareness, phoneme–grapheme correspondences) in Kiswahili and English, whereas children in the control condition did not. Overall results supported bidirectionality of relations, such that children's literacy skills in the two languages were reciprocally related over time. However, directionality of relations differed as a function of language and literacy instruction condition, such that the relation from English to Kiswahili was found across intervention conditions, but the relation from Kiswahili to English was found only among children who had received explicit instruction in Kiswahili reading. These results are discussed in light of theory and practice for language and literacy acquisition in multilingual contexts.

Keywords Linguistic interdependence · Bidirectional · Kenya · Transfer · Instruction

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11145-018-9889-7) contains supplementary material, which is available to authorized users.

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Introduction

Tens of millions of children live in contexts in which they are expected to acquire literacy skills in more than one language. Unfortunately, many children in multilingual contexts, particularly those from developing countries, have extremely low achievement in reading even after years of instruction (Dowd, Wiener, & Mabeti, 2010; Friedlander, Gasana, & Goldenberg, 2014; Gove & Cvelich, 2011; Wasanga, Ogle, & Wambua, 2010). Therefore, it is critical to identify factors that influence reading achievement of one distinct but large world population: those acquiring literacy in more than one language in developing countries. The goal of our study was to expand our knowledge of the nature of developmental relations of early literacy skills in two languages, using longitudinal data from Kenya from beginning of Grade 1 to end of Grade 2. In particular, we examined whether literacy skills in two languages had bidirectional relations and whether the nature of literacy instruction (whether children received explicit and systematic instruction on key components or not) influenced the relations between languages.

An influential theory regarding language and literacy acquisition in multiple languages is Cummins' (1979, 2000) linguistic interdependence hypothesis, which states that children's second-language (L2) proficiency is, to some extent, a function of their first-language (L1) competence. The central idea is that proficiencies in cognitively demanding tasks such as literacy, content learning, and abstract thinking are common across languages, such that proficiency in L1 transfers to learning in another language (i.e., L2). Specifically, Cummins (1979) hypothesized that three central aspects of L1 reading acquisition—vocabulary conceptual knowledge, metalinguistic insights about functions of print, and facility in processing decontextualized language—were important to L2 acquisition. Although Cummins' hypothesis did not explicitly consider multilingual acquisition beyond L2, the general hypotheses and principles appear to apply to this context (Cenoz, 2003; Cenoz & Genesee, 1998).

The linguistic interdependence is a rather broad conceptual framework, encompassing a wide range of knowledge and skills (see Ball, 2011; Dutcher, 1994; Koda & Reddy, 2008, for reviews). When the framework was operationalized empirically, a large number of studies focused on phonological awareness and word reading in the context of cross-language transfer (Bialystok, 2007; Branum-Martin, Tao, Garnaat, Bunta, & Francis, 2012; Luk & Bialystok, 2008) with some others addressing vocabulary, story comprehension, and retelling (Cenoz, 2003; Durgunoğlu, Mir, & Ariño-Martí, 1993a; Proctor, August, Carlo, & Snow, 2006).

Phonological awareness refers to the ability to recognize and manipulate various sizes of sound units, and is one of the most critical skills for word reading in alphabetic languages (Adams, 1990; National Institute of Child Health and Human Development [NICHD], 2000; Snow, Burns, & Griffin, 1998; Wagner & Torgesen, 1987). It is considered a type of metalinguistic awareness, and as such was hypothesized to transfer from L1 to L2. Indeed, a large body of studies has shown correlations between phonological awareness in L1 and L2, and between L1 phonological awareness and L2 word reading across various language pairs

(e.g., English–Spanish, English–French, English–Korean, English–Japanese, and English–Chinese. August & Shanahan, 2006; Branum-Martin et al., 2006; Cisero & Royer, 1995; Comeau, Cormier, Grandmaison, & Lacroix, 1999; Durgunoğlu, Nagy, & Hancin-Bhatt, 1993b; Durgunoğlu & Oney, 1999; Kim, 2009; Kuo, Uchikoshi, Kim, & Yang, 2016; Saiegh-Haddad & Geva, 2008; Wang, Park, & Lee, 2006b. For reviews, see Branum-Martin et al., 2012; Koda & Reddy, 2008; Melby-Lervåg & Lervåg, 2011). Expanding the correlational evidence, causal evidence was recently reported in cross-language transfer of phonological awareness (Wawire & Kim, 2018).

In addition to phonological awareness, word reading skills have been shown to be related across language pairs, particularly when the focal languages have similar writing systems (i.e., alphabetic orthography). For instance, in a study with Arabic-speaking children learning English in Canada, Abu-Rabia and Siegel (2002) reported relations of word reading skills between Arabic and English, ranging from $r = .30$ to $r = .85$ (Saiegh-Haddad & Geva, 2008). Similar findings were reported for English-speaking children learning French (Comeau et al., 1999); Spanish-speaking children learning English (Branum-Martin et al., 2006; Durgunoğlu et al., 1993a, 1993b; Kim, 2012); Korean-speaking children learning English (Kim, 2009; Wang et al., 2006b); children learning in three languages—Hebrew, Arabic, and English—in Canada (Abu-Rabia & Siegel, 2003) and in Russian, Hebrew, and English in Israel (Schwartz, Geva, Share, & Leikin, 2007); and those learning in various L1s, Kiswahili, and English in Kenya (Piper, Schroeder, & Trudell, 2016b). In contrast, languages that employ writing systems that are different in terms of what orthographic symbols fundamentally represent (e.g., sound vs. meaning as in English vs. Chinese), cross-language transfer of word reading skills might not as readily occur (Luk & Bialystok, 2008; Wang, Cheng, & Chen, 2006a; Wang, Yang, & Cheng, 2009).

These previous studies have provided a wealth of insight into language and literacy development in multiple languages. However, there are several important limits to our understanding about literacy acquisition in multilingual contexts. One gap is about the nature of transfer. One of the basic tenets of the linguistic interdependence hypothesis (Cummins, 1979, 2000) is bidirectionality or reciprocity. If proficiencies in cognitive tasks such as reading are common underlying resources across languages, and acquisition in one language facilitates transfer to learning of other languages, then transfer may occur bidirectionally—that is, L1 literacy acquisition would influence L2 literacy acquisition; and literacy acquisition in L2 also would influence L1 literacy skills. However, the linguistic interdependence hypothesis has been primarily studied to explain L2 competence as a function of L1 competence (i.e., the L1-to-L2 transfer), not bidirectional relations.

An important corollary is the role of environment in directionality. The common assumption in previous studies has been that L1 influences L2 because L1, by definition, should be a more familiar language in which the child is proficient and, therefore, skills developed in L1 would transfer to L2, supporting L2 literacy skill acquisition. However, when it comes to literacy acquisition, the nature of L1 and L2 relations may vary as a function of *literacy instruction environments*. In many multilingual contexts, particularly in the Global South (Africa, Latin America, and

developing Asian countries), L2 is the official language or the "target" language and, thus, receives greater or at times sole attention and emphasis in literacy instruction (Akyeampong, Pryor, Westbrook, & Lussier, 2011; Jones & Barkhuizen, 2011). In these contexts, then, transfer may occur from L2 to L1, as long as there is sufficient exposure to L2 and motivation to learn L2 (Cummins, 1986). Therefore, the language in which literacy skills are acquired first, regardless of language status (L1 or L2), helps literacy acquisition in other languages.

On the other hand, not just exposure itself but instructional environment might play a role in the extent of transfer. If instruction targets metalinguistic awareness such as phonological awareness and the alphabetic principle, explicitly capitalizing on the link between target languages, this might facilitate transfer to a greater extent than instruction without such intentional attention. For example, drawing explicit attention to how letter sounds in one language are similar to or different from sounds in the other language may promote transfer more readily than if no such explicit instruction were present. In the present study, we investigated the role of instructional environment in the extent of transfer, using randomized controlled trial data where students learned L1 and L2[1] under different conditions (i.e., a treatment condition where metacognitive skills were explicitly and systematically taught, and a control condition where these were absent). Specifically, children in the treatment conditions were taught phonological awareness, alphabet letters, phonics, and reading comprehension strategies explicitly and systematically in Kiswahili and in English. Children in the control condition received business-as-usual instruction, which primarily used the whole-word or "look and say" method, without any of the explicit instruction in the skills noted above (Commeyras & Inyega, 2007; Dubeck, Jukes, Brooker, Drake, & Inyega, 2015). The language of instruction in the control schools was typically English, although the Kiswahili subject was primarily taught in the Kiswahili language (Piper & Miksic, 2011).

Another important gap in the literature is cross-language relations of literacy skills beyond lexical-level skills (i.e., reading fluency and reading comprehension). Previous studies primarily have focused on sublexical (i.e., phonological awareness) and lexical-level skills (i.e., word reading or decoding; see above), with an exception being a study by Baker, Stoolmiller, Good, and Baker (2011) on cross-language relations between oral reading fluency and reading comprehension. Evidence also has suggested positive relations of reading comprehension between languages (Baker et al., 2011; Manis, Lindsey, & Bailey, 2004; Proctor et al., 2006; Wang et al., 2006a), but these were all cross-sectional bivariate correlations and did not examine longitudinal bidirectional relations. Since the proposal of the interdependence hypothesis about four decades ago, studies have revealed that higher-order cognitive skills such as inference-making, perspective taking, and comprehension monitoring, in addition to vocabulary and grammatical knowledge, are important to reading comprehension (Cain & Oakhill, 2007; Cain, Oakhill, & Bryant, 2004; Kim, 2015b, 2017; Oakhill & Cain, 2012; Oakhill, Hartt, & Samols, 2005; van den

[1] Note that although we are using the terms L1 and L2, these languages might be L2 and L3 for some children in multilingual contexts.

Broek, Kendeou, Lousberg, & Visser, 2011). If these higher-order cognitive skills are underlying common proficiencies across languages, reading comprehension in L1 and L2—both of which draw on these higher-order cognitive skills—should be related. Gottardo, Javier, Farnia, Mak, and Geva (2014) found that although students' L1 (Spanish) word reading predicted L2 (English) reading comprehension), L2 word reading did not predict L1 reading comprehension. As noted, in the present study, using longitudinal data, we examined instead whether reading comprehension in two languages was bidirectionally related.

Finally, the majority of previous studies have been conducted in the context of L1 and L2, although data are emerging from contexts with more than two languages (Abu-Rabia & Siegel, 2003; Cenoz, 2003; Schwartz et al., 2007). Theoretically, the core principles of the above-noted linguistic interdependence hypothesis are expected to work similarly whether the student's language is L2, L3, or L4 (Cenoz & Genesee, 1998). Many children in multilingual contexts are in fact learning to read in their L2 and L3 for various reasons (e.g., L1 or mother tongue is not one of the official languages and/or language of broader communication, or teachers with proficiency in the students' local language are not available; Kim, Boyle, Zuilkowski, & Nakamura, 2016). The present study was conducted in the multilingual context of Kenya (see below for further details).

Present study

The primary goal of the present study was to expand our understanding about cross-language transfer in literacy skills over time, using longitudinal data from children learning to read in English and Kiswahili in Kenya. The guiding research questions were as follows: (a) Do literacy skills in English and Kiswahili have bidirectional relations for Grade 1 and 2 children in Kenya?; (b) If they do, does the nature of the bidirectional relations differ as a function of instructional approaches and environments (i.e., intervention condition compared with control)?

To address these questions, children's literacy skills at sublexical (letter-sound knowledge), lexical (word decoding), and text levels (oral reading fluency and reading comprehension) were assessed longitudinally at three time points: beginning of first grade (time 1), end of first grade (time 2), and end of second grade (time 3). The rationale behind the selection of this set of skills was as follows. Letter-sound knowledge, or the understanding of letter–sound correspondences, is the best predictor of word reading or decoding (Adams, 1990; Ehri, 1998; Muter, Hulme, Snowling, & Stevenson, 2004; NICHD, 2000; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Although sounds for corresponding alphabet letters are script-specific, an important aspect of letter-sound knowledge is the alphabetic principle—an understanding that orthographic symbols represent sounds—which involves metalinguistic insights about functions of print, and thus, transfers across languages (Wawire & Kim, 2018).

Decoding proficiency is the foundational skill for oral reading fluency—i.e., fast and accurate reading of connected texts (Fuchs, Fuchs, Hosp, & Jenkins, 2001; Kim, 2015a; Kim, Wagner, & Foster, 2011; NICHD, 2000) and reading comprehension

(Florit & Cain, 2011; Hoover & Gough, 1990; Joshi, Tao, Aaron, & Quiroz, 2012). Decoding skill (as measured by one's ability in reading words and nonwords) is built on one's knowledge and awareness of phonology, morphology, and orthography (Carlisle & Katz, 2006; Kim, 2011; Kim, Apel, & Al Otaiba, 2013; Nagy, Berninger, Abbott, Vaughan, & Vermeulen, 2003; Schatschneider et al., 2004), and therefore, is expected to transfer across languages; studies indeed have provided between-language correlations (see above). Oral (text) reading fluency is a reading skill at the level of connected text, and is built on decoding skill as well as oral language comprehension (Jenkins, Fuchs, van den Brock, Espin, & Deno, 2003; Kim, 2015b; Kim, Park, & Wagner, 2014; Kim & Petscher, 2011). Although an oral language skill such as vocabulary is language specific (i.e., understanding labels for concepts, although conceptual knowledge is language independent) and thus is not likely to readily transfer across languages, oral reading fluency as a construct would transfer across languages to the extent that it captured decoding skills and associated metalinguistic awareness. One study showed that oral reading fluency between L1 and L2 was moderately related for Spanish-speaking English learners in the United States (Baker et al., 2011).

Finally, reading comprehension draws on all these skills: letter-sound knowledge, decoding skill, and oral reading fluency (Gough & Tunmer, 1986; Hoover & Gough, 1990; Johnston & Kirby, 2006; Joshi et al., 2012; Kim, 2015a; Vellutino, Tunmer, Jaccard, & Chen, 2007). Moreover, reading comprehension relies on oral language proficiency (vocabulary, grammatical knowledge, and listening comprehension) as well as cognition (working memory, attention, inference, perspective taking, and comprehension monitoring (Barnes, Dennis, & Haefele-Kalvaitis, 1996; Cain, 2007; Cain et al., 2004; Conners, 2009; Cromley & Azevedo, 2007; Daneman & Merikle, 1996; Elleman, Lindo, Morphy, & Compton, 2009; Kim, 2015b, 2017). Among these, higher-order cognitive skills are particularly good candidates for cross-language transfer, in line with Cummins' speculation about abstract thinking skills. Therefore, reading comprehension would be correlated between languages; and studies have shown that students' performance in reading comprehension in L1 and L2 is weakly (Proctor et al., 2006) to moderately related (Baker et al., 2011; Manis et al., 2004).

Characteristics of Kenya's literacy instruction environment

Kenya has a complex language environment that has implications for literacy instruction. Kenya has two official languages, Kiswahili and English, and its citizens speak more than 40 languages (Lewis, Simons & Fennig, 2015; Republic of Kenya, 2010). Similar to many countries in sub-Saharan Africa, Kenya has had a language policy encouraging the use of the language of the "catchment area" since 1976 (Republic of Kenya, 1976, p. 54). However, parents and communities resist the utilization of local language in schools (Bunyi, 2008), and this results in heavy pressure at the local level to employ English as the language of instruction (Trudell, Young, & Nyaga, 2015). Empirical evidence has suggested that the vast majority of instructional time in the subject areas is in English, even in rural communities with relative language homogeneity (Piper & Miksic, 2011). Even when explicit

interventions are undertaken to support local language use in the subject areas, instructional time remains predominantly in English (Piper, Zuilkowski, Kwayumba, & Oyanga, 2018c). While the language-of-instruction policy for pre-primary education is to use the local language, English predominates (African Population and Research Center, 2018).

Kiswahili has a unique place in Kenyan language policy. Kiswahili has its roots in the complex language development of traders on the Swahili coast up and down East Africa, and has connections to Bantu languages in sub-Saharan Africa and to Arabic. Unlike in Tanzania, where Kiswahili is the official language of instruction nationally, Kenya's language policy expects Kiswahili to be utilized as the language of instruction in urban and peri-urban areas (Republic of Kenya, 1976), although this policy is seldom followed (Piper & Miksic, 2011). Kiswahili is seen by communities as of more value instructionally than other local languages, given that it is a subject on the Kenya Certificate of Primary Education examinations for all students. While Kiswahili is not the L1 for a large percentage of children, it is a language of broader communication that unites Kenyans of different ethnic groups who have various levels of English proficiency. Kiswahili is an agglutinating language, and while fluency outcomes in Kenya might be lower in Kiswahili than in English, reading comprehension is higher (Piper et al., 2016b). A typical Kenyan child is expected to learn at least three languages: a mother tongue (or the language of the local community); the lingua franca, Kiswahili; and English. Many of the mother tongues are related to Kiswahili and have similar Bantu language features. In the context of this study, the local language was typically Kiswahili, or in some cases, English.

Kiswahili uses the Roman alphabet (same as English). However, unlike English, the letter–sound correspondences are consistent. Despite this shallow orthography, however, evidence from multiple recent studies showed that learning outcomes in Kenya were lower than expected, particularly in Grades 1 and 2 (Piper, 2010; Uwezo, 2016; Wasanga et al., 2010). Given the low achievement levels, the Kenyan Ministry of Education commissioned several interventions to improve literacy outcomes in several parts of the country (Jukes et al., 2016; Lucas, McEwan, Ngware, & Oketch, 2014). The Primary Math and Reading (PRIMR) program was one such initiative, and provided the data analyzed in this paper. PRIMR (2011–2014) was implemented predominantly in urban and peri-urban settings, which means that the participating children had a heightened likelihood of having oral proficiency in Kiswahili and some exposure to oral English, as well as the written English used in classrooms. The program included 547 schools, of which 229 were in Nairobi's slum areas, where PRIMR worked with low-cost private schools serving these communities.

The instructional approach in PRIMR took advantage of the transparent orthography of Kiswahili, as well as the multilingual nature of Kenya's children, and the oral language facility of children in Kiswahili. The PRIMR program provided books for Grade 1 and 2 pupils at a 1:1 ratio in both Kiswahili and English; 10 days of training per year for teachers, divided into three sessions prior to the three terms in Kenya's education calendar; and continuous instructional support from government Curriculum Support Officers or project-employed coaches. Instructionally, PRIMR teachers

taught pupils skills that have been shown to be important from research in developed countries (NICHD, 2000; Snow et al., 1998) such as phonemic awareness, phonics, and decoding, including word-attack strategies and practice. Students were intentionally introduced to letters and letter sounds in Kiswahili before they were taught these same letters in English, so that the letters taught in English were taught in connection with what children had already learned in Kiswahili. In the first weeks of the English program in Grade 1, teachers focused on expanding English oral language skills before they introduced letters and decoding in English, so as to support a balanced bilingual literacy program.

In addition to the decoding taught in PRIMR, the program also ensured learners' ongoing practice in reading connected texts in both languages on a daily basis, plus an expanded set of pre-reading and during-reading strategies for improving comprehension and practice in various writing genres. Lessons were 30 min long for both languages (Kiswahili and English), and children were given specific reinforcement activities to implement at home, including additional decoding activities, reading stories, and writing practice. This program showed consistently statistically significant effects—between 0.2 and 1.0 standard deviations *(SD)*—on learning outcomes in both Kiswahili and English (Piper, King, & Mugenda, 2016a; Piper, Zuilkowski, & Mugenda, 2014); and documented that the coaching model for supporting teaching was effective (Piper & Zuilkowski, 2015b). While the PRIMR study did not undertake formal fidelity-to-implementation analyses, the scale-up of PRIMR, called the Tusome Early Grade Reading Activity, showed that the majority of teachers were teaching nearly 80% of the Tusome English and Kiswahili lessons (Piper, DeStefano, Kinyanjui, & Ong'ele, 2018a).

PRIMR's instructional approach capitalized on underlying principles in learning to read in the two target languages, in large part because the existing instructional environment in Kenya did not do so. Research in Kenya has shown that the dominant method for teaching literacy in English and Kiswahili is having pupils repeat words the teacher says (Commeyras & Inyega, 2007; Dubeck et al., 2015) and that the predominant unit of focus is at the word level rather than the letters or syllables that constitute the words (Jukes et al., 2016). Outside of PRIMR, there was no explicit connection between Kiswahili and English. In the government's curriculum, they were designed as separate subjects and were taught with no connection between the letter sounds that differed between the two languages. For example, the different letter sounds that vowels have in Kiswahili compared with English were not explicitly taught in the non-PRIMR literacy materials.

Method

Participants and sites

The PRIMR longitudinal data utilized in this study came from a larger PRIMR data set from the four counties implementing the PRIMR Initiative from 2012 to 2013 in Grades 1 and 2. The counties were selected by the Ministry of Education given their representativeness of the rest of the country. In Kenya's education system, counties

are organized into zones, which are groups of 12–30 schools. The selected zones were randomly assigned to treatment and control groups using random selection and random assignment. The schools for the longitudinal subsample were drawn from these randomly assigned zones using proportional-to-population sampling. Although the primary effects of the initiative on student achievement and examination of teacher training model have been reported elsewhere (Piper et al., 2016a; Piper et al., 2014), the bidirectional relations have not been reported. Data were collected from these children in January 2012, at the beginning of Grade 1 (time 1); October 2012, the end of Grade 1 (time 2); and October 2013, the end of Grade 2 (time 3). At the beginning of the study, a total of 996 children participated. However, by the end of Grade 2, this number had been reduced to 628, an attrition rate of 37.0%. The data set utilized in this study was composed of the 628 children (312 female) who had data at each of the three time points. There were 357 treatment and 271 control children, and mean age at the beginning of Grade 1 was 6.34 years ($SD = 0.99$), with a range of 4–10 years old.

The children in the sample had access to pre-primary education, with 96.0% of the sampled children stating that they had attended some form of formal or informal pre-primary education. However, few children entered Grade 1 with knowledge of their letter sounds (see below). Previous research from PRIMR showed that there was a substantial gap between the learning outcomes of children of different socioeconomic status, and that the program improved the learning outcomes of the poor substantially, yet not enough to reduce the gap (Piper, Jepkemei, & Kibukho, 2015).

The PRIMR data collection protocol required that the assessors go back to the schools assessed at the baseline sample and determine whether the children assessed at baseline were still in the school. If they were not present, the PRIMR assessor would select a child of the same gender sitting closest to where the initially assessed child was sitting, rather than following up at the household to identify where the child actually was. Although this was a cost- and time-effective resampling option, it did contribute to higher attrition (Thomas et al., 2012). The 37.0% attrition rate in the PRIMR longitudinal data was slightly less than the 41% attrition rate experienced in Kenya's household survey data (Alderman, Behrman, Kohler, Maluccio, & Watkins, 2001), but higher than a recent longitudinal study on repetition in Uganda (Kabay, 2016). Given the literature that suggests that longitudinal and repeated cross-sectional results can differ (Almond & Sinharay, 2012), we examined the relationship between the longitudinal results and the cross-sectional results of the impact of PRIMR and found no meaningful differences in the magnitude of those impacts (Piper et al., 2016a).

We compared the baseline characteristics of the students who remained in the longitudinal study with those who were no longer available at the endline study on 19 different variables collected at the beginning of Grade 1. We found that those who were in the endline longitudinal analysis group were 6% more likely to have a phone in the household ($p = .04$), were 9% less likely to have electricity in their house ($p < .01$), were 11% more likely to have a bicycle in the house ($p < .01$), and were 0.1 years younger ($p = .04$) than those who were not in the endline group. The average effect size of those differences was 0.00 *SD,* suggesting that variability between these groups was no different than might have

been identified by chance. Previous empirical research from Kenya on attrition has suggested that background characteristics can be correlated with attrition rates, and that doing so does not create systematic bias in household demographic research (Alderman et al., 2001). The literature on whether attrition rates affect bidirectional relations between language outcomes is nascent, however, and we address the potential impacts in our section on threats to validity.

Measures

Children's reading skills were evaluated at sublexical, lexical, and text levels. These skills were assessed by widely used measures, including tools from both developed countries (Dynamic Measurement Group, 2008) and developing countries (Gove & Cvelich, 2011). The larger data set included results for several additional skills that were not assessed at all three time points (e.g., English vocabulary and Kiswahili listening comprehension), but the subset of longitudinal data did include letter-sound fluency, decoding fluency (or nonword fluency), oral reading fluency of connected text, and reading comprehension in both English and Kiswahili, gauged via a set of tools typically called the Early Grade Reading Assessment (EGRA; Gove & Wetterberg, 2011). A recent summary of the concurrent validity results from EGRA showed five developing-country contexts in which the assessment was compared with other internationally utilized measures (Dubeck, Gove, & Alexander, 2016). Kenya's EGRA scores had a 0.96 and 0.98 concurrent validity with the Uwezo Initiative assessments, utilized across East Africa (Australian Council for Educational Research, 2015). In India, correlations between EGRA and the Annual Status of Education Report results were between 0.9 and 0.94 (Vagh, 2012). Below, we present the specific measures analyzed in this study.

Letter-sound fluency

Letter-sound fluency refers to the number of letter sounds correctly identified per minute. Working one-on-one with each sampled pupil, an assessor provided the children with an array of 100 letters, in a mixture of upper and lower case, presented in random order on a laminated sheet. The children were asked to identify the sound of each letter. In English, letters—particularly vowels—represent multiple sounds. Therefore, canonical sounds were expected (e.g., for letter *c,* the expected sound is /k/, and for letter *a*, the expected sound is /æ/). This reasoning aligns with that of widely used letter-sound fluency tasks in the United States (e.g., those in the aimsweb screening system developed by NCS Pearson, Inc.). Reliability at the final assessment for English letter-sound fluency was 0.85 and for Kiswahili letter-sound fluency was 0.89. Letter-sound fluency outcomes ranged from 0 to 160.6 letter sounds correct per minute for English, and 0–171.4 letter sounds correct per minute for Kiswahili.

Decoding fluency

Children's decoding skill was assessed by the nonsense word fluency task. Each child was presented with an array of 50 nonwords (or pseudowords) and was asked to read the words accurately within a minute. The measure was derived from the number of nonsense words correctly identified per minute. Items in the English task were derived by adapting words with a consonant–vowel–consonant pattern such that they were decodable by applying grapheme–phoneme correspondences in English. Reliability estimates for nonsense word fluency were 0.86 for Kiswahili and 0.82 for English at the final assessment. Nonsense word fluency outcomes ranged from 0 to 90.0 nonsense words correct per minute for English, and 0–90.9 nonsense words correct per minute for Kiswahili.

Oral reading fluency

Children's oral reading fluency was measured using a narrative story of approximately 60 words designed for them to read aloud (see Online Resource 1). Fluency rates were derived from the number of words correctly read per minute from the narrative story. The reliability estimates for oral reading fluency were 0.86 for Kiswahili and 0.81 for English for the final assessment. Oral reading fluency outcomes ranged from 0 to 159.8 correct words per minute for English, and 0–137.6 correct words per minute for Kiswahili.

Reading comprehension

Reading comprehension was assessed using a set of five comprehension items for each round (see Online Resource 1). Questions that related to the 60-word oral reading fluency passage, interspersed at similar intervals, were asked of the children based on how much of the story they read. If they could not read any words in the passage, they were not asked the reading comprehension questions, and no credit was given on the reading comprehension measure. Reading comprehension is a multifaceted construct and is measured in various ways. In particular, many comprehension measures distinguish and include literal and inferential questions. Literal comprehension refers to one's understanding of what is explicitly stated in the text (Pearson & Johnson, 1978), whereas inferential comprehension is an understanding of what is not explicitly specified but implied in the text—that is, "read[ing] between the lines" (Basaraba, Yovanoff, Alonzo, & Tindal, 2013, p. 354). In the present study, many questions were related to literal comprehension, although an inferential question was also included (see Online Resource 1). The rationale for using a greater number of literal questions was to prevent floor effects, as inferential comprehension is expected to be more difficult (Cain & Oakhill, 1999).

The results were reported in terms of the percentage of comprehension questions answered correctly. Reliability estimates for reading comprehension were 0.87 for Kiswahili and 0.83 for English at the final assessment. English reading comprehension outcomes ranged from 0% correct to 100% correct, although with the usage of post-test linear equating methods, some of the scores were considered 125% correct

to compare appropriately with other rounds of the assessment (Albano & Rodriguez, 2012). For Kiswahili, reading comprehension outcomes ranged from 0 to 100% correct, although utilizing linear equating measures, some of the scores were considered 106.5% correct for comparison with other assessment rounds.

Procedures

Assessment procedures

The assessors in this study were part of a team that was trained over a several-year period in larger studies with a focus on early literacy outcomes. The assessors were trained for 5 days in Nairobi, with three rounds of group testing to assess their rating consistency so that those assessors who performed poorly during the training could be dismissed before the fieldwork began. During the training, assessors were taken to field sites for piloting with children, and their work was managed by a field supervisor who observed the quality of their data collection. During the second and third rounds of full data collection, when the PRIMR assessors used electronic tablets rather than paper and pencil, the data quality manager checked results each evening and gave the assessors feedback on any missing data before they began data collection the next day. The average interrater reliability scores were 96, 96, and 93% for the three rounds of data collection, respectively. These average scores were achieved after the individuals had completed their reliability assessments and any unreliable assessors had been removed from the data collection teams.

Instructional procedures

The PRIMR Initiative was designed to provide ongoing training and instructional support to teachers participating in the treatment portion of the intervention, using the new program tools, during the life of PRIMR. During the period reviewed in this paper, a teacher would have received 10 days of professional development in both 2012 and 2013. Of those 10 total days, approximately 2 would have focused on mathematics improvement, meaning that direct face-to-face trainings during the 2 years of the PRIMR program summed to 16 days for literacy, or 8 days per year. Professional development sessions took place at the beginning of each of the three terms every academic year, for between 2 and 5 days per term. The sessions were led by the government's Curriculum Support Officers, who supported between 12 and 30 public schools; or by program-contracted instructional coaches, who supported either 10 or 15 low-cost private schools. Curriculum Support Officers or coaches worked in pairs during the training, and had oversight from the Kenyan government system's technical officers as well as the PRIMR Initiative technical team. Between the terms, teachers were observed by the Curriculum Support Officers or the instructional coaches in their classrooms. These observations focused on a full 30-min Kiswahili or English lesson and culminated in a constructive feedback session afterward with the teacher, which addressed two or three areas for instructional improvement. The observational tool emphasized instructional activities that

PRIMR deemed essential, including specific skills needed for bilingual language transfer in Kenya's literacy environment. Classroom observational data suggest that teachers frequently used the PRIMR materials and methods, that the usage of these materials increased the amount of time teachers used research-based literacy methods, and that the Curriculum Support Officers and coaches increased their observational frequency much more than occurred in control schools (Zuilkowski & Piper, 2017). Although PRIMR did not collect fidelity-of-implementation data, the scaled-up version of PRIMR, Tusome, showed high levels of implementation (Piper et al., 2018a,c).

Teachers in the control condition continued to utilize the same methods that they used prior to PRIMR—i.e., no explicit or systematic instruction on letter–sound correspondences. Instruction primarily focused on whole-class instruction, using the whole-word "look and say" method, whereby teachers would point to a word, say the word aloud, and ask the children to repeat the word. For reading comprehension, control teachers primarily relied on asking factual recall questions after reading passages. This was the case across both languages, Kiswahili and English.

Data analysis

For each literacy outcome, we fit cross-lagged path models with auto-regressors and correlations between languages at the same time point, in order to examine bidirectional relations across three time points (see Fig. 1). Given that data were drawn from two groups of children (i.e., one treatment and one control), we fit the cross-lagged path models using multigroup analysis (i.e., fitting the models for both groups simultaneously; see Thompson & Green, 2013), using Mplus 7.0 (Muthén & Muthén, 1998–2012). Given floor effects in a few variables, particularly during the early phase of development, we used a weighted least square estimator, WLSMV. We evaluated the model fits using the following indices: Chi square statistics, comparative fit index (CFI), the Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residuals (SRMR). RMSEA values below 0.08, CFI and TLI values equal to or greater than 0.95, and SRMR equal to or less than 0.05 indicate an excellent model fit (Hu & Bentler, 1999; Kline, 2005).

Results

Descriptive statistics

Data missingness was minimal. For the majority of variables, there were no missing data. Exceptions were as follows: Data for English oral reading fluency were missing for one child in the treatment condition (0.2%) at time 1; data for reading comprehension in English and Kiswahili were missing for seven children (1.1%; six children in the control condition, and one child in the treatment condition) at time 1.

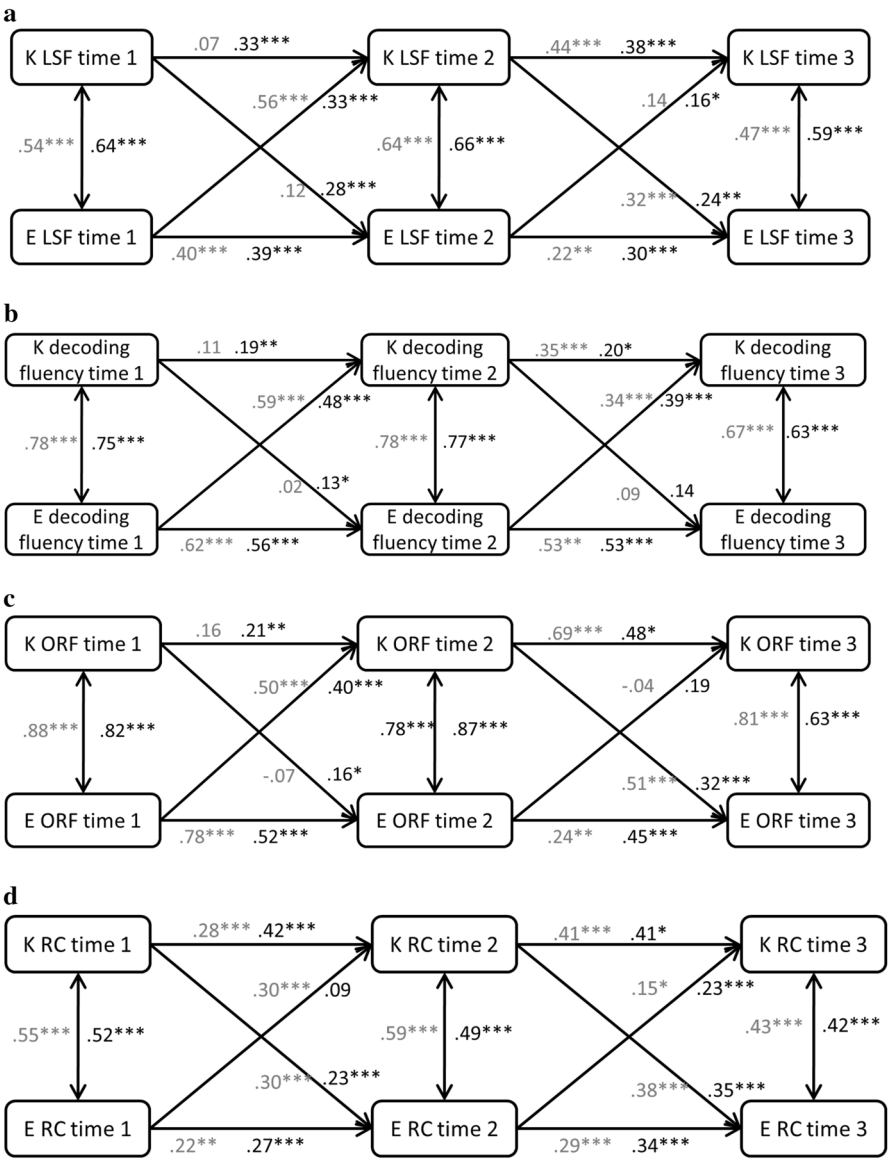

Fig. 1 Standardized structural regression weights between Kiswahili (K) and English (E) for the following literacy skills: letter-sound fluency (LSF; **a**); decoding fluency (**b**); oral reading fluency (ORF; **c**); and reading comprehension (RC; **d**). *Note*: The first, gray sets of coefficients are for control condition; second, black sets of coefficients are for treatment condition. Time = assessment time point 1, 2, or 3. $^{*}p < .05$; $^{**}p < .01$; $^{***}p \leq .001$

Table 1 presents descriptive statistics for the full sample as well as by treatment condition. As expected, students' scores in all the tested skills improved over time across groups. For instance, these children (full sample), on average, were able to

Table 1 Descriptive statistics for full sample and by intervention status

Variable	Full sample				Treatment				Control			
	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max
K LSF time 1	12.59	9.79	0.00	53.00	13.33	10.34	0.00	53.00	11.61	8.94	0.00	42.00
K LSF time 2	38.47	26.25	0.00	139.53	46.44	27.15	0.00	139.53	27.97	20.81	0.00	88.00
K LSF time 3	44.68	33.13	0.00	171.43	55.73	34.35	0.00	171.43	30.13	24.86	0.00	100.00
E LSF time 1	17.31	16.94	0.00	72.00	18.14	17.52	0.00	72.00	16.21	16.13	0.00	71.00
E LSF time 2	33.51	27.58	0.00	160.65	42.41	28.58	0.00	160.65	21.79	21.14	0.00	117.14
E LSF time 3	43.97	32.42	0.00	153.16	56.59	32.30	0.00	153.16	27.35	24.03	0.00	96.00
K DF time 1	2.70	6.14	0.00	35.00	2.69	6.42	0.00	35.00	2.71	5.76	0.00	35.00
K DF time 2	11.96	13.24	0.00	68.78	12.89	14.39	0.00	68.78	10.73	11.46	0.00	60.00
K DF time 3	22.09	17.41	0.00	90.91	23.66	18.48	0.00	90.91	20.02	15.69	0.00	77.84
E DF time 1	5.40	8.81	0.00	61.25	5.38	8.72	0.00	61.25	5.42	8.95	0.00	46.00
E DF time 2	18.55	17.01	0.00	80.00	20.18	18.31	0.00	76.22	16.40	14.88	0.00	80.00
E DF time 3	27.59	18.70	0.00	90.00	30.35	19.78	0.00	90.00	23.96	16.51	0.00	72.31
K ORF time 1	3.11	7.48	0.00	50.00	3.26	7.92	0.00	50.00	2.93	6.86	0.00	46.00
K ORF time 2	18.98	17.27	0.00	88.98	20.60	18.86	0.00	88.98	16.86	14.68	0.00	81.97
K ORF time 3	33.27	24.35	0.00	137.64	36.16	26.99	0.00	137.64	29.46	19.77	0.00	109.40
E ORF time 1	4.40	10.68	0.00	79.02	4.64	11.33	0.00	79.02	4.10	9.77	0.00	62.55
E ORF time 2	25.77	28.37	0.00	146.71	28.42	29.86	0.00	136.23	22.27	25.93	0.00	146.71
E ORF time 3	43.17	33.69	0.00	159.83	47.53	36.69	0.00	159.83	37.42	28.33	0.00	136.97
K RC time 1	0.04	0.12	0.00	0.80	0.04	0.13	0.00	0.80	0.04	0.12	0.00	0.80
K RC time 2	0.20	0.23	0.00	0.93	0.22	0.24	0.00	0.93	0.17	0.21	0.00	0.74
K RC time 3	0.36	0.31	0.00	1.06	0.39	0.33	0.00	1.06	0.32	0.26	0.00	1.06
E RC time 1	0.02	0.09	0.00	0.60	0.02	0.09	0.00	0.60	0.03	0.09	0.00	0.60
E RC time 2	0.11	0.16	0.00	0.77	0.11	0.16	0.00	0.77	0.10	0.16	0.00	0.77

Table 1 (continued)

Variable	Full sample				Treatment				Control			
	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max
E RC time 3	0.31	0.39	0.00	1.25	0.36	0.43	0.00	1.25	0.24	0.32	0.00	1.25

The values for reading comprehension (RC) are decimals such that, for example, the mean of .31 represents 31%

SD standard deviation, *K* Kiswahili, *E* English, *LSF* letter-sound fluency, *DF* decoding fluency, *ORF* oral reading fluency and *RC* reading comprehension

correctly identify letter sounds for 13 Kiswahili letters per minute at time 1. This rate increased to approximately 39 letters at time 2 and approximately 45 letters at time 3. The sizes of improvements were larger for children in the treatment condition, as reported in an earlier study (see Piper et al., 2014). Interestingly, at baseline (i.e., time 1) across treatment conditions, children's mean performances were higher in English than in Kiswahili, although the sizes of the mean differences were larger in sublexical skills (e.g., letter-sound fluency) than in higher-order skills (e.g., reading comprehension). Mean differences between English and Kiswahili using full sample data were as follows: letter-sound fluency ($\Delta = 4.71$, $df = 627$, $p < .001$), decoding word fluency ($\Delta = 2.69$, $df = 627$, $p < .001$), and oral reading fluency ($\Delta = 1.30$, $df = 626$, $p < .001$). In reading comprehension, despite overall low performances in both languages, children's mean performance was higher in Kiswahili than in English ($\Delta = 0.02$, $df = 613$, $p < .001$). Mean differences between Kiswahili and English within the treatment condition can be found in "Appendix 1".

Floor effects were observed in all the assessed literacy skills, but more severely in decoding fluency, oral reading fluency, and reading comprehension, particularly at time 1. For instance, at time 1, 74 and 68% of the children were not able to read a single nonword in Kiswahili and English, respectively (not shown in Table 1). In reading comprehension, 86 and 92% of the children scored 0 in reading comprehension Kiswahili and English respectively. These floor effects are certainly not ideal and are an important weakness of the present study. However, it is important to note that they reflect the widely recognized low literacy achievement status of many children in developing countries (Gove & Cvelich, 2011). Also note that floor effects are on a continuum in terms of severity; and that there were variations around the means in the skills with floor effects. Therefore, it was deemed important to examine the potential presence of relations using available data. Because transformations did not make notable differences in distributional properties, subsequent analyses reported here are based on raw scores.

Table 2 displays correlations between measures across time points. Relations were in the expected directions, ranging from weak ($r = .11$ for English letter-sound fluency at times 2 and 3, and English reading comprehension at time 1) to very strong ($r = .90$ for Kiswahili and English oral reading fluency at time 2).

Bidirectional relations

We fit cross-lagged path models for each of the literacy outcomes: Letter-sound fluency, decoding fluency, oral reading fluency, and reading comprehension. For each outcome, autoregressors and correlations between Kiswahili and English at each time point were allowed.

The model fit for letter-sound fluency (LSF) was excellent: $\chi^2\,(8) = 12.01$, $p = .15$; CFI = 1.00; TLI = .99; RMSEA = .04 (.00–.083); and SRMR = .023. Results for the LSF outcomes are presented in Fig. 1a. From time 1 to time 2, the relation from English to Kiswahili was moderate across treatment conditions ($\beta = .56$ for control and $\beta = .33$ for treatment, $ps < .001$). In contrast, the relation of Kiswahili to English was statistically significant only for the treatment group ($\beta = .28$, $p < .001$), but not

Table 2 Correlations between tasks

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. K LSF 1	–																						
2. K LSF 2	.48	–																					
3. K LSF 3	.34	.58	–																				
4. E LSF 1	.61	.54	.36	–																			
5. E LSF 2	.46	.80	.53	.51	–																		
6. E LSF 3	.32	.55	.72	.30	.56	–																	
7. K DF 1	.45	.28	.19	.42	.24	.13	–																
8. K DF 2	.49	.63	.40	.52	.56	.34	.55	–															
9. K DF 3	.32	.47	.58	.35	.41	.45	.35	.58	–														
10. E DF 1	.50	.40	.32	.57	.37	.22	.76	.64	.43	–													
11. E DF 2	.53	.65	.41	.57	.63	.37	.53	.87	.59	.64	–												
12. E DF 2	.40	.54	.60	.42	.53	.58	.35	.58	.76	.46	.64	–											
13. K ORF 1	.42	.28	.22	.42	.23	.15	.91	.54	.37	.77	.53	.36	–										
14. K ORF 2	.53	.65	.42	.54	.59	.39	.55	.89	.61	.65	.90	.65	.56	–									
15. K ORF 3	.36	.50	.57	.37	.48	.47	.38	.59	.82	.44	.62	.79	.39	.65	–								
16. E ORF 1	.42	.32	.28	.42	.28	.21	.82	.56	.40	.81	.58	.42	.84	.59	.45	–							
17. E ORF 2	.53	.64	.42	.58	.59	.37	.59	.85	.57	.69	.91	.62	.59	.90	.60	.67	–						
18. E ORF 3	.43	.58	.60	.48	.58	.54	.40	.67	.79	.53	.71	.88	.42	.73	.83	.50	.73	–					
19. K RC 1	.39	.27	.19	.37	.17	.14	.78	.49	.30	.64	.45	30	.82	.47	.33	.70	.51	.35	–				
20. K RC 2	.50	.59	.37	.52	.53	.34	.46	.74	.46	.60	.76	.53	.46	.80	.51	.51	.80	.62	.45	–			
21. K RC 3	.34	.48	.54	.35	.43	.45	.32	.54	.74	.42	.57	.73	.34	.61	.83	.39	.58	.80	.29	.53	–		
22. E RC 1	.24	.14	.17	.28	.11	.11	.55	.31	.25	.49	.36	.22	.57	.35	.30	.69	.46	.31	.54	.36	.26	–	
23. E RC 2	.42	.46	.30	.52	.46	.28	.46	.60	.44	.56	.63	.45	.47	.64	.43	.55	.74	.57	.39	.62	.45	.38	–
24. E RC 3	.42	.54	.51	.44	.48	.48	.36	.55	.55	.46	.55	.62	.37	.57	.58	.41	.60	.74	.36	.56	.62	.31	.54

All the coefficients are statistically significant at the .05 level

K Kiswahili, *E* English, *LSF* letter-sound fluency, *DF* decoding fluency, *ORF* oral reading fluency and *RC* reading comprehension

for the control group ($\beta = .12$, $p = .06$). From time 2 to time 3, the relation from English to Kiswahili was weak but statistically significant only for the treatment condition ($\beta = .16$, $p = .03$; for the control condition, $\beta = .14$, $p = .07$). The relation from Kiswahili to English was statistically significant for both groups ($\beta = .32$, $p < .001$ for control, $\beta = .24$ for treatment, $p = .001$).

For the decoding fluency outcome, model fit was excellent as well: χ^2 (8) = 9.19, $p = .32$; CFI = 1.00; TLI = 1.00; RMSEA = .022 (.00–.072); and SRMR = .014. Results are presented in Fig. 1b. From time 1 to time 2, English decoding fluency was positively and moderately related to Kiswahili decoding fluency across the groups ($\beta = .59$ for control, $\beta = .48$ for treatment, $ps < .001$). Kiswahili decoding fluency was weakly related to English decoding fluency and was statistically significant only for the treatment group ($\beta = .13$, $p = .03$; for control group, $\beta = .02$, $p = .75$). From time 2 to time 3, English decoding fluency was moderately related to Kiswahili for both groups ($\beta = .34$ for control, $\beta = .39$ for treatment, $ps < .001$). However, the relation of Kiswahili to English was weak and not statistically significant for either group ($\beta = .09$, $p = .35$ for control, $\beta = .14$ for treatment, $p = .09$).

When the outcome was oral (text) reading fluency (ORF; see Fig. 1c), the model fit was good: χ^2 (8) = 19.57, $p = .01$; CFI = 1.00; TLI = .99; RMSEA = .068 (.030–.107); and SRMR = .016. From time 1 to time 2, there were positive and moderate relations from English to Kiswahili for both treatment and control groups ($\beta = .50$ for control, $\beta = .40$ for treatment, $ps < .001$). From Kiswahili to English, there was a weak, but statistically significant relation for the treatment group ($\beta = .16$, $p = .02$), but not for the control group ($\beta = -.07$, $p = .42$). From time 2 to time 3, there was a moderate and statistically significant relation of Kiswahili to English for both treatment ($\beta = .32$, $p < .001$) and control groups ($\beta = .51$, $p < .001$). In contrast, the relation from English to Kiswahili was weak and not statistically significant for either the treatment condition ($\beta = .19$, $p = .06$) or the control condition ($\beta = -.04$, $p = .68$).

When the outcome was reading comprehension (see Fig. 1d), the model fit was good: χ^2 (8) = 19.01, $p = .01$; CFI = .99; TLI = .97; RMSEA = .066 (.028–.105); and SRMR = .027. From time 1 to time 2, the relation of English to Kiswahili was significant for the control condition ($\beta = .30$, $p < .001$) but not for the treatment condition ($\beta = .09$, $p = .12$) whereas there was a statistically significant relation for both groups from Kiswahili to English ($\beta = .30$ for control, $\beta = .23$ for treatment, $ps < .001$). From time 2 to time 3, the relation of Kiswahili to English was moderate ($\beta = .38$ for control, $\beta = .35$ for treatment, $ps < .001$) while the relation of English to Kiswahili was weak but statistically significant ($\beta = .15$, $p = .04$ for control, $\beta = .23$ for treatment, $p < .001$).

A graphic summary of these results is presented in Fig. 2. A few patterns are worth noting. First, from English (time 1) to Kiswahili (time 2) to English (time 3), bidirectional relations were consistent across treatment conditions for the majority of literacy skills. An exception was decoding fluency, for which the relation of Kiswahili (time 2) to English (time 3) was not statistically significant for either group. On the other hand, the relation from Kiswahili (time 1) to English (time 2) was observed for decoding-related skills such as letter naming fluency, decoding fluency, and oral reading fluency only for children in the treatment condition. However,

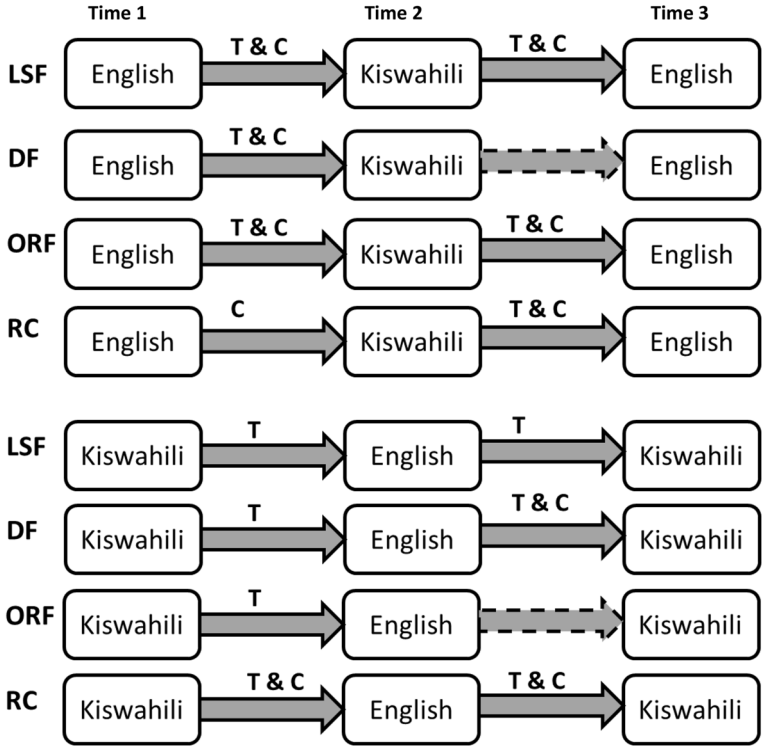

Fig. 2 Summary of results for bidirectional relations for letter-sound fluency (LSF), decoding fluency (DF), oral reading fluency (ORF), and reading comprehension (RC). *Note*: T represents treatment and C represents control condition. Solid arrows represent statistically significant relations; arrows with dashed lines represent non-statistically-significant relations

from English (time 2) to Kiswahili (time 3) in these reading skills, there was no consistent pattern. For reading comprehension, across the conditions, Kiswahili (time 1) was related to English (time 2), which, in turn, was related to Kiswahili (time 3).

Discussion

Literacy acquisition in one language involves complex and dynamic processes, and it is even more complex in multilingual contexts. According to the linguistic interdependence hypothesis (Cummins, 1979), children who are learning to read in a second language can benefit from abilities already acquired in the first language, because skills such as literacy, content-area knowledge, and problem-solving are common, underlying skills that transfer across languages. Similar principles have been recognized in literacy acquisition in L3 and beyond (Cenoz, Hufeisen, & Jessner, 2001; Schwartz et al., 2007). In the present study, we aimed to empirically examine this hypothesis in two important aspects—the bidirectionality of relations

and the instructional approach in which reading is acquired—using longitudinal data from children acquiring literacy skills in Kiswahili and English in Kenya.

The overall findings of the present study do provide evidence of the bidirectional relations between languages. As shown in Figs. 1 and 2, bidirectional relations existed in most of the literacy skills, after we accounted for autoregressors. Children's literacy skills in English at time 1 predicted their skills in Kiswahili at time 2, which, in turn, was related to English literacy skills at time 3. Similarly, Kiswahili literacy skills at time 1 were related to English literacy skills at time 2, which, then, were related to Kiswahili literacy skills at time 3. These results extend previous studies by examining beyond the unidirectional L1 to L2 relations, and indicate that literacy skills in multiple languages have bidirectional relations. As stated previously, bidirectionality is important in the linguistic interdependence hypothesis, but the vast majority of previous studies have focused on L1-to-L2 transfer.

The present findings highlight the importance of considering instructional context in bidirectional relations and literacy acquisition in multilingual settings. In many multilingual contexts such as the Global South, literacy instruction is available only in L2; even when literacy instruction is available in L1, L2 skills are more heavily emphasized due to perceived social and economic importance (Akyeampong et al., 2011; Trudell & Piper, 2013). This was the case in Kenya, such that although Kiswahili and English are both official languages, English is given greater importance for social upward mobility. As a result, despite the local language policy promoting L1 (also called mother tongue) or Kiswahili use, in many classrooms English is the de facto language of instruction (Piper & Miksic, 2011). This trend is reflected to some extent in the higher mean scores in English, even at the beginning of first grade (see Table 1), despite the facts that (a) Kiswahili either was the participating children's L1 or was more closely related to their L1 than English; (b) literacy acquisition in Kiswahili is easier due to its transparent orthography; and (c) literacy instruction in either Kiswahili or English does not officially start until first grade. Previous results have shown that this dependence on English as the predominant language of literacy instruction results in inefficient literacy skill acquisition in both L1 and L2 (Piper et al., 2016b).

We speculate that this heightened attention to and perceived importance of English explain the consistent finding that English literacy skills at time 1 were related to Kiswahili at time 2, which then was related to English at time 3, *regardless of* the treatment conditions or instructional approaches (see the top panel in Fig. 2). In other words, children in Kenya are exposed to literacy in English even before schooling, and then skills in Kiswahili are developed at school, which supports further expansion of English skills by Grade 2. While the PRIMR treatment capitalized on the orthographic transparency of Kiswahili and taught skills in Kiswahili first before transitioning to English, classroom observations revealed a heavier emphasis in many classrooms on English and preference for English in the other subjects (Piper et al., 2018c).

In contrast, we observed a statistically significant relationship between Kiswahili and English from time 1 to time 2 in decoding-related skills (i.e., letter-sound fluency, decoding fluency, and oral reading fluency) but this was the case only for children in the treatment condition, not for those in the control condition. This could

have been due to the instructional approach employed in the treatment condition, whereby instruction was carefully sequenced and organized to capitalize on Kiswahili's more shallow orthography and children's greater facility with oral Kiswahili, which then were explicitly linked to English instruction. As described above, letters and letter sounds in Kiswahili were introduced from the first week of instruction, and when letters were later introduced in English, they were taught in reference to those in Kiswahili. Therefore, this explicit instruction in the treatment condition promoted transfer of knowledge and principles (or metacognitive awareness) gained during Kiswahili reading acquisition (see Wawire & Kim, 2018, for causal evidence of transfer of metalinguistic awareness).

The pattern of relations from Kiswahili to English to Kiswahili (see the bottom panel in Fig. 2) was somewhat different for reading comprehension, such that the relation was found for children in the treatment and control conditions. Although we do not have empirical evidence to explain this different pattern, one difference between reading comprehension and the other outcomes is that reading comprehension requires not only decoding skills but also oral language proficiency and higher-order cognition (Cain et al., 2004; Cromley & Azevedo, 2007; Kim, 2015b, 2017). Thus, the students, regardless of the treatment condition, drew on their skills in Kiswahili at time 1, which then influenced English at time 2, which, again, influenced Kiswahili reading comprehension. However, according to this reasoning, a similar pattern of relations should have been found for the treatment group from English at time 1 to Kiswahili at time 2. As shown in the top panel in Fig. 2, the relation from English to Kiswahili was statistically significant only for children in the control condition. Future studies should investigate the nature of transfer of reading comprehension skills between languages by measuring students' language and cognitive skills in both languages and by examining their interrelations over time.

Although not the focal question in the present study, it is notable that children's reading comprehension skills in English and Kiswahili remained low even after 2 years of instruction (see Table 1). While previous research in the PRIMR program showed significant impacts on learning outcomes, the baseline performance was quite low, and many children still struggled to read (Piper, Zuilkowski, Dubeck, Jepkemei, & King, 2018b). A recent study from an extension of PRIMR to rural settings in Kenya showed that several ingredients were necessary to improve learning outcomes. These included teacher professional development and instructional coaching, as well as the improved textbooks that PRIMR used. The addition of teachers' guides with structured lesson plans described in the PRIMR model was also shown to be a cost-effective intervention (Piper et al., 2018b). Even with these elements, learning outcomes remained below what Kenyan children need, indicating that additional instructional interventions are required.

An additional important factor to recognize is complexity of reading comprehension. Evidence is clear that reading comprehension is a higher-order skill that involves complex information processing such as understanding propositions, connecting them across the text and with one's background knowledge, and integrating them to construct a coherent mental model (Kim, 2017; Kintsch, 1988; van den Broek, Rapp, & Kendeou, 2005). This process requires numerous memory and attentional resources as well as language (vocabulary, grammatical knowledge, and

discourse skills), cognition (e.g., inference, perspective taking), and print-related skills (e.g., decoding; Barnes et al., 1996; Cain, 2007; Cain et al., 2004; Cromley & Azevedo, 2007; Daneman & Merikle, 1996; Elleman et al., 2009; Kendeou, van den Broek, White, & Lynch, 2009; Kim, 2015b, 2017). Not surprisingly, studies have shown that development of reading comprehension takes a long time (Chall, 1983; Wanzek & Vaughn, 2007; Wanzek, Wexler, Vaughn, & Ciullo, 2010) and requires multiple, sustained years of explicit and systematic instructional attention to the component skills noted above (Kim et al., 2016).

In summary, findings of the present study have important theoretical and practical implications. From a theoretical perspective, bidirectional relations as well as directionality as a function of instructional environments would extend basic tenets of the linguistic interdependence hypothesis. As noted earlier, the linguistic interdependence hypothesis has been widely conceptualized and studied in the context of L1-to-L2. An extension of this hypothesis to an L2-to-L1 relationship is a critical step to substantiate the hypothesis of common underlying proficiencies.

Our research contributes to the understanding of the directionality of relations as a function of instructional environments. If skills acquired in reading are transferrable to acquisition in another language, the instructional environment in which reading is taught is important. If the key component skills of reading (e.g., phonological awareness) are explicitly and systematically taught in a language (either L1 or L2), then, the direction of the relation is expected to be from the language of systematic instruction to the other language. It is important to note that this principle would not negate the importance of oral language proficiency in L1 and instructional approaches capitalizing on children's L1 proficiency. On the contrary, extant evidence (Branum-Martin et al., 2006; Melby-Lervåg & Lervåg, 2011; Wawire & Kim, 2018) as well as the present study supports an approach of utilizing children's facility in language and associated cognition in L1 (the language in which the child is most proficient) to build foundational literacy skills where logistically possible to do so (Ball, 2011; Kim et al., 2016; PASEC, 2015; Piper, Zuilkowski, & Ong'ele, 2016c).

Practically, our findings suggest that it is critical for planners to understand the typical instructional and language environments while developing instructional interventions. Designing programs with a theoretical understanding of the importance of L1 alone is not sufficient; more effective and efficient programs will examine and consider what skills are being taught in what languages and build careful improvement programs with the existing language and instructional environment in mind. Teaching letter sounds, decoding skills, oral reading fluency, and reading comprehension, among other skills, is important to improve educational outcomes in L1 and L2.

Limitations and future directions

The present findings should be interpreted with the following limitations in mind. First, the findings are from children in low-resource contexts who learn two languages which use alphabetic writing systems. Therefore, the generalizability of

findings should be limited to similar populations. Second, although it is widely acknowledged—and our fieldwork did validate—the fact that Kiswahili and English are widely used in the communities and schools in the four counties where the study was conducted, we did not formally assess students' oral language proficiency in Kiswahili and English, for two reasons: (a) our focus was on cross-language transfer of *literacy* skills; and (b) there were no available oral language measures in Kiswahili with sufficient reliability and validity information. Literacy acquisition is the outcome of multiple language, cognitive, and print-related skills. The main interest in the present study was the bidirectional relations of literacy skills over time (as a result of language and cognitive component skills), and therefore, inclusion of various language and cognitive skills was beyond the scope. Third, as noted earlier, there were floor effects in the literacy skills; as such, the results of bidirectionality should be interpreted cautiously with this in mind. Although this outcome reflects the reality of poor literacy achievement in developing countries in general and Kenya specifically, and the weighted least squares (WLSMV) estimator was used in the analysis, this is an important weakness because the relations were likely attenuated due to reduced variance. Despite the reduced variance, we did find relations between time 1 and time 2. It is unknown, however, the extent to which magnitudes of relations were impacted by reduced variance in literacy skills, particularly at time 1. In addition, although possible, we do not believe this is a function of the difficulty level of the assessments used in the study, because the measures previously had been both piloted and used in large-scale work in Kenya and other contexts (Gove & Cvelich, 2011; Piper & Zuilkowski, 2016). Fourth, the reading comprehension assessment was brief, including a single passage and five questions. Despite previous research suggesting that results on two passages were not significantly different from each other (Piper & Zuilkowski, 2015a), future work should include multiple passages and a greater number of comprehension questions.

Fifth, attrition was high in this study, which limits generalizability of the findings to some extent. The final longitudinal data set suffered from 37.0% attrition from those initially assessed at time 1. Although not ideal, this level of attrition in a 2-year longitudinal study is not uncommon (Alderman et al., 2001; Al Otaiba, Kim, Wanzek, Petscher, & Wagner, 2014), and a recent study showed that attrition rate did not influence estimates of association between variables as long as attrition was not dependent on *both* baseline and follow-up variables (Gustavson, von Soest, Karevold, & Røysamb, 2012), which was the case in the present study. It is possible that bidirectional relations could be systematically different between learners included in the final data set and those who left the data set. The plausibility of this explanation seems low, however, given that the learning outcomes were very similar between the PRIMR longitudinal and cross-sectional analyses presented elsewhere (Piper et al., 2016a) and there was no discernible pattern in the differences of those who were in the final data set and those who attrited. Future work should invest in tracing children at their homes, communities, and other schools and examine

whether these children are significantly different from those who remained in the study (Thomas et al., 2012).

Finally, to our knowledge, this is the first study that has examined bidirectional relations with longitudinal data on sublexical, lexical, and text-reading skills. Therefore, it would be important to replicate the present study in different language pairs and contexts. An interesting extension of the present study would be whether cross-language transfer depends on the level of proficiency in the target skills (e.g., decoding) according to the threshold hypothesis, which states that a minimum threshold in language proficiency needs to be met before transfer occurs (Cummins, 1979).

The bidirectional relations found here suggest transfer of reading skills between two languages, similar to what was suggested for Kenya in previous literacy work, although without the advantages of longitudinal data (Piper et al., 2016b). In addition, explicit instruction on emergent literacy skills (i.e., letter sounds) in a language familiar to the child, with explicit attention to similarities between target languages, appeared to promote transfer—even when children were not taught in their actual non-Kiswahili L1—if both (or all) the languages used a similar script (Piper et al., 2016b). This finding indicates the importance of evidence-based reading instruction methods in both L1 and L2. In particular, if the goal is to promote L2 literacy by capitalizing on children's resources in L1, then systematic instruction in L1 is necessary beyond early reading and decoding skills. This is the case for higher-order reading skills such as reading comprehension. Prior studies have shown that children can achieve high proficiency in lexical-level literacy skills in L2 with evidence-based instruction (Lesaux & Siegel, 2003), but struggle in reading comprehension due to limited oral language proficiency (Lesaux, Rupp, & Siegel, 2007; Melby-Lervåg & Lervåg, 2014 for an alternative view, see Kieffer, 2011; López, Scanlan, & Gorman, 2015). Given growing evidence that oral language proficiency at the discourse level (e.g., listening comprehension) requires development of higher-order cognitive skills (Florit, Roch, & Levorato, 2014; Kim, 2015b; Kim & Phillips, 2014; Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012; Tompkins, Guo, & Justice, 2013), explicit and systematic instruction in these skills is likely necessary to promote reading comprehension in L1 (López et al., 2015), which then can transfer to L2 reading comprehension. This requires a future empirical examination.

Acknowledgements The Primary Math and Reading (PRIMR) Initiative was funded by the United States Agency for International Development (USAID/Kenya), under the Education Data for Decision Making (EdData II) Blanket Purchase Agreement, Task Order No. AID-623-M-11-00001 (RTI International Task 13). The second author served as the Chief of Party on the PRIMR Initiative. The contents of the article are the sole responsibility of the authors. The authors' views expressed in this publication do not necessarily reflect the views of USAID, the United States Government, or RTI International.

Appendix 1

See Table 3.

Table 3 Mean differences between Kiswahili and English

Variable	Treatment			Control		
	Δ *M*	*t* (*df* = 356)	*p*	Δ *M*	*t* (*df* = 270)	*p*
LSF time 1	−4.81	−6.74	< .001	−4.59	−5.58	< .001
LSF time 2	4.03	4.10	< .001	6.17	6.63	< .001
LSF time 3	−0.86	−0.62	.54	2.77	2.11	.04
NWF time 1	−17.48	−21.06	< .001	−13.69	−17.39	< .001
NWF time 2	−7.29	−14.72	< .001	−5.67	−12.60	< .001
NWF time 3	−6.68	−9.48	< .001	−3.95	−6.32	< .001
ORF time 1	−1.41	−4.01	< .001	−1.17	−3.90	< .001
ORF time 2	−7.83	−10.12	< .001	−5.41	−5.95	< .001
ORF time 3	−47.14	−24.46	< .001	−37.10	−21.72	< .001
RC time 1	0.02	3.78	< .001	.02	2.76	.006
RC time 2	0.11	10.71	< .001	.07	7.93	< .001
RC time 3	0.02	1.36	.17	.08	5.06	< .001

Reference language is Kiswahili; therefore, negative values represent lower means in Kiswahili

LSF letter-sound fluency, *NWF* nonword fluency, *ORF* oral reading fluency and *RC* reading comprehension

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