

Auditory Support to Assist Learning in Linguistically Diverse Classrooms:

Factors Related to the Use of Bilingual Text-to-Speech Technology

Abstract

Text-to-speech technology can act as an important support tool in computer-based learning environments (CBLEs) as it provides auditory input, next to on-screen text. Particularly for students who use a language at home other than the language of instruction (LOI) applied at school, text-to-speech can be useful. The CBLE E-Validiv offers content in the LOI and one of six other languages. All content can be read aloud via text-to-speech. For students having a home language other than the LOI, the other language is set to their home language; students who use the LOI at home mostly have English or French available. This study aimed to determine fifth-grade students' use of bilingual text-to-speech and examine student characteristics related to this use (n=360). Multilevel hierarchical regression analyses show that particularly students having their home language available apply text-to-speech in their home language. However, their main focus remains on text-to-speech in the LOI. Students with a low self-assessed proficiency in their home language and those who often watch television and read books in the LOI use text-to-speech more in the LOI. Considerations for practice, the design of CBLEs with text-to-speech, and future directions for research are discussed.

Keywords: auditory support; modality; text-to-speech; linguistic diversity; home language; computer-based learning environment

1. Introduction

Recent advancements in technology enable the integration of different support tools in computer-based learning environments (CBLEs). These can help to facilitate learning (Brett, 1995) and to respond to students' needs and preferences (Dalton & Strangman, 2006). One of these support tools is text-to-speech (TTS) technology, which converts digital text to spoken language. Hence, auditory information is offered in combination with visual information, without the direct presence of, for example, a teacher (Leslie, Low, Jin, & Sweller, 2012). This can be particularly useful for students who face serious challenges to comprehend the information provided in CBLEs and to achieve the high literacy demands related to it (e.g., Proctor, Dalton, & Grisham, 2007), such as language minority students who speak a language at home other than the language of instruction (LOI), which is used for instruction and interaction in the classroom and school context.

The way various groups of learners apply these new technologies in CBLEs and how they process auditory information combined with visual information are important questions for research into multimedia environments (Plass, Chun, Mayer, & Leutner, 1998; Vandergrift, 2007). This can help in gaining insights into the support students in general, and language minority students in particular, need in such CBLEs (Vandergrift, 2007). Accordingly, the development of adaptive systems with learner-controlled options can support students' needs and preferences, make content more accessible, and thus, enhance learning (Brett, 1995; Plass et al., 1998).

Despite the potential of TTS to support students' learning process, research on how TTS can be integrated and used in CBLEs is still limited. There is a particular lack in research about the potential supportive nature of TTS for language minority students. Therefore, the present study focuses on a CBLE which offers bilingual auditory support (i.e., in the LOI and another language) through TTS technology, next to bilingual on-screen text. This study aims

to examine the use of bilingual TTS in the CBLE and how it is related to learner characteristics regarding students' home language, the LOI, background, and learning achievement. In the following, we will first discuss why TTS should be considered for CBLEs and how it can strengthen the learning process through combining visual and auditory input. Moreover, we will look at student characteristics likely related to the use of TTS in a CBLE.

2. Theoretical background

2.1 Why should TTS be integrated in a CBLE?

There are different reasons to integrate TTS into CBLEs, as these are information-rich and contain mainly textual information. First, through the simultaneous offer of information in a visual and auditory way, struggling readers can remove barriers for comprehension (e.g., because of decoding and fluency problems), appeal to different representations, and thus access information more easily (Dalton, Pisha, Eagleton, Coyne, & Deysher, 2002; Dalton & Strangman, 2006; Lundberg & Olofson, 1993; Proctor et al., 2007; Wald, 2008). This can free space in working memory, thereby reducing cognitive overload (Sweller, 2010). Hence, students can focus on meaning construction, which is the actual goal of reading (Dalton & Strangman, 2006; Proctor et al., 2007). This also implies that they can read age-appropriate material at their proper grade and interest level (Dalton & Strangman, 2006).

Second, auditory text is expressed in an authentic way, which makes it less difficult to understand when students have difficulty with reading comprehension (Brett, 1995; Chang, Tseng, & Tseng, 2011; Porter & Roberts, 1981). At the same time, listening is transitory, implying that spoken information has to be processed quickly as working memory only has limited capacity (Moussa-Inaty, Ayres, & Sweller, 2012; van den Broek, Segers, & Verhoeven, 2014; Yang, 2014). However, the combination with visual input can help to fix

this issue, as visual text can remain longer in memory (Chang et al., 2011; Moussa-Inaty et al., 2012).

Third, language minority students, who often speak a language at home other than the LOI used at school, face an extra challenge: they have to acquire new literacy skills at school, just like all students, but they also have to do it in the LOI, which they have often not yet fully mastered (Goldenberg, 2008). The achievement gap between language minority and language majority students (Martin, Mullis, Foy, & Stanco, 2012; OECD, 2010; Author citation, 2014) also indicates that language minority students experience more difficulties to attain the same achievement level as their language majority peers, who use the same language at home as the LOI applied at school. Offering language minority students support in their home language can be a viable means to overcome this challenge by assisting them in the mastery of content in the LOI through the appeal to their home language (Sierens & Van Avermaet, 2014). Moreover, as language minority students mostly use their home language orally with their family, giving access to TTS to decode written content in their home language can actually help them to surmount obstacles if their reading skills in their home language are not strongly developed.

Language minority students need support in both oral language development and reading skills to become highly proficient in literacy in the LOI (August & Shanahan, 2006). Hence, the integration of TTS into CBLEs can be considered as a way to accommodate to students' personal needs, thereby enabling a more adaptive and individually supportive approach, for example for language minority students (Dalton & Strangman, 2006). Some CBLEs already aim to support language minority students in their learning process through offering content in their home language, for example by means of TTS technology. The Universal Literacy Environment offers web-based English texts to improve vocabulary development and reading comprehension, particularly for native Spanish speakers (Dalton & Proctor, 2007; Dalton,

Proctor, Uccelli, Mo, & Snow, 2011). Through TTS, the text, directions, and instructional supports can be read aloud both in English and Spanish (Dalton & Proctor, 2007). HELP Math (Help with English Language Proficiency) is a web-based additional mathematics curriculum focused on the development of both mathematical vocabulary and proficiency in the LOI (i.e., English) for English Language Learners (Freeman, 2012). Audio support is available in Spanish. In the Wolves Project, a Web-based Inquiry Science Environment (WISE), students can access content in both English and Spanish (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Drews, 2012). They can choose to turn audio support on in both languages, for example to hear the explanation of a concept. Finally, bilingual multimedia storybooks allow to listen to a story in both the LOI and language minority students' home language while it is shown on screen (e.g., Edwards, Monaghan, & Knight, 2000).

Despite these promising initiatives, there is a lack of research regarding factors which determine the use of TTS. Studies on the aforementioned CBLEs mostly consider a whole range of different support tools, without focusing on the use of TTS in itself. Moreover, research on support tools in CBLEs generally focuses on the impact of the tools on learning outcomes. However, Belland and Drake (2013) state that this is problematic, as it starts from the expectation that the tools have the same impact on different students. Therefore, it is important to know how students with different characteristics make use of the support tools offered to them, as the differential use can also have an impact on learning outcomes (Clarebout & Elen, 2006; Giesbers, Rienties, Tempelaar, & Gijsselaers, 2013). For example, less successful learners often ignore support that would be beneficial to them (Proctor et al., 2007). Particularly in light of the incorporation of TTS in CBLEs as a support tool for language minority students' learning process, it is necessary to determine the characteristics that play a role in the use of TTS in both the home language and the LOI.

2.2 Combining visual and auditory information

Learning opportunities offered by technology have more chance to be effective if they are adapted to the way the human cognitive system operates (Mayer, 2010). Otherwise, the available support tools may inhibit rather than facilitate learning (Leslie et al., 2012). Accordingly, integrating TTS technology in CBLEs with textual information is supported by the assumption that the combined presentation of two modalities, such as visual and auditory text, can foster students' learning process through the access of information via two channels (Dalton & Strangman, 2006; Lundberg & Olofson, 1993; Proctor et al., 2007). Modality refers to the information-processing channel which a learner uses to process information (Moreno, 2006). Presentations simultaneously using the auditory modality (e.g., spoken words through the ears) and visual modality (e.g., on-screen text through the eyes) are dual-modality or audiovisual presentations (Kalyuga, 2012). This is the kind of presentation we focus on in this study.

The audiovisual way of presenting is based on the dual-channel assumption, one of the main assumptions of the cognitive theory of multimedia learning (Mayer, 2010) and strongly related to Baddeley's (1992) work. This assumption states that "humans possess separate information processing channels for visually represented material and auditory represented material" (Mayer, 2010, p. 33). Working memory consists of two systems which can simultaneously process information, namely the auditory and visual system. However, they can only hold a limited number of elements for a limited amount of time (Baddeley, 1992; Chandler & Sweller, 1992; Moreno & Mayer, 2002; van Merriënboer & Sweller, 2005). When students simultaneously read and hear a text, they process the written information in visual working memory and the corresponding spoken information in auditory working memory (Moreno & Mayer, 2002). Hence, the capacity of working memory is extended if two modalities are applied (Moreno & Mayer, 1999). Moreover, misunderstandings in one

modality can be moderated through the other modality (Mayer & Moreno, 1998). Türk and Erçetin (2014) have also shown that learners are more engaged and achieve higher when they simultaneously receive verbal and visual information, compared to allowing them to choose the kind of input. Thus, it is assumed that students benefit more from dual modality than single modality for both retention and transfer (Kalyuga, 2012; Mayer, Heiser, & Lonn, 2001; Moreno & Mayer, 2002).

However, according to the redundancy principle, learning may be impeded when students receive the same information through different modalities because of a heightened cognitive load (Chandler & Sweller, 1991; Leslie et al., 2012; Sweller, 2010). This may imply that verbal redundancy, or the simultaneous presentation of spoken and written text with identical words (Kalyuga, 2012; Moreno & Mayer, 2002), can decrease performance because of an excessive working memory load (Sombatteera & Kalyuga, 2012). Yet, the research results on this verbal redundancy effect remain inconclusive. While some studies have reported that learning with verbally redundant presentations does not improve performance (Acha, 2009; Chang et al., 2011; Craig, Gholson, & Driscoll, 2002; Jamet & Le Bohec, 2007; Kalyuga, Chandler, & Sweller, 1999, 2000, 2004; Mayer et al., 2001; Moussa-Inaty et al., 2012; Pastore, 2012), others have found positive effects of verbal redundancy for learning (Bird & Williams, 2002; Lewandowski & Kobus, 1993; Montali & Lewandowski, 1996; Moreno & Mayer, 2002; Mousavi, Low, & Sweller, 1995; Ritzhaupt, Gomes, & Barron, 2008). Besides, most studies revealing negative effects of verbal redundancy combine audio and on-screen text with animations or pictures (e.g., diagrams), which may likely overload the visual channel (Ritzhaupt, Pastore, & Davis, 2015). When no other competing visual information is presented simultaneously with on-screen text, redundant verbal messages promote learning more than nonredundant verbal explanations (Moreno & Mayer, 2002).

In this study, the focus lies on how the comprehension of visual text can be supported by auditory input, without the inclusion of animations. It is also necessary to consider the reason to integrate TTS in a CBLE: to increase proficiency in a specific language or to increase comprehension (Moussa-Inaty et al., 2012). The purpose of TTS in the present study is primarily to enhance comprehension. From their meta-analysis, Adesope and Nesbit (2012) also conclude that students learning from spoken-written presentations outperform those learning from spoken-only presentations. This is particularly applicable to learners with low prior knowledge, system-paced learning materials, and picture-free materials. No differences were found between spoken-written presentations and written-only presentations. According to Adesope and Nesbit (2012), the mixed outcomes in verbal redundancy studies and the difficulty of drawing conclusions about learning effects can be ascribed to a considerable extent to learner characteristics.

2.3 Characteristics likely related to the use of TTS in a CBLE

The former section concluded with the point that learner characteristics can play a role in the way TTS is applied in CBLEs. Plass and colleagues (1998) state that the most effective way to address individual differences is to present students with both visual and verbal options, so that they can actively select and process material. However, the relationship between individual learner characteristics and the use of digital supports, such as TTS, needs to be understood more clearly before the impact of TTS on achievement can be determined (Dalton & Strangman, 2006).

Regarding the integration of audiovisual support in language minority students' home language in a CBLE, Kalyuga (2012) states that particularly students for whom the LOI is not their home language may benefit from a narration with simultaneous on-screen text. Adesope and Nesbit's (2012) meta-analysis also shows that particularly language minority students

who need to learn the LOI as a second language can benefit from spoken-written presentations.

Concerning the proficiency in the language in which TTS is available, Mueller (1980) has shown that, compared to single modality, dual modality is useful as a compensatory strategy for students with a low proficiency level in the language under study. Students who are highly proficient in a language attain the same results when receiving audiovisual material as when using material in only one modality (Mueller, 1980). In Chang and colleagues' (2011) study, students with low English proficiency who learned simultaneously with written text and spoken messages experienced less extraneous load than those who learned with spoken messages only. The combination of written text with spoken messages also gave students with low English proficiency sufficient time to process and store new information in long-term memory, thereby enhancing their listening comprehension. In contrast, students with high English proficiency could rely more on prior knowledge about English. This helped them to connect new information to already existing knowledge in long-term memory, thus resulting in lower intrinsic load (cf. Sweller, van Merriënboer, & Paas, 1998).

Related to this, students' reading level may also play a role in the use of TTS (Dalton & Strangman, 2006). For example, Verhoeven (1990) has shown that reading comprehension in the LOI is strongly influenced by oral proficiency in the LOI for Turkish-speaking language minority students at the beginning of formal instruction. Hence, students learning to read in the LOI should get support to develop their oral skills in the LOI to strengthen reading instruction in that language. Montali and Lewandowski (1996) have found that providing less skilled readers with audiovisual support can make them feel more confident about their comprehension, compared to single modality. Adesope and Nesbit's (2012) meta-analysis also indicates that particularly struggling readers benefit from presentations combining spoken and written words. They may use the spoken content to compensate for failed

comprehension of written content or vice versa. This may imply that verbal redundancy is particularly useful to foster reading comprehension for struggling readers. For example, Dalton and Proctor (2007) have found that struggling readers frequently rely on TTS support in a CBLE to gain access to challenging text.

As comprehension is dependent on knowledge that is not always directly traceable from a single word or sentence (Whitehurst & Lonigan, 1998), the access to and use of different linguistic resources can also influence students' use of bilingual auditory support. For example, regularly reading books in a language can strengthen proficiency in word recognition, vocabulary, strategy use, and reading fluency (Echols, West, Stanovich, & Zehr, 1996; Guthrie Wigfield, Metsala, & Cox., 1999; Leppänen, Aunola, & Nurmi, 2005). This helps students in their text comprehension and in their development towards proficient readers (Guthrie, Schafer, & Huang, 2001; Juel, 1988; Sénéchal & LeFevre, 2002). Moreover, reading frequency extends general knowledge (Cox & Guthrie, 2001; Cunningham & Stanovich, 1997), for example by experiencing new ideas (Juel, 1988). Watching television can also lead to incidental vocabulary learning and increased comprehension (Webb & Rodgers, 2009). For example, comprehension skills acquired in one medium, such as television, can transfer to reading (Kendeou et al., 2005). Thus, through contact with oral and written language both inside and outside school, children can acquire literacy skills spontaneously (Elley & Mangubhai, 1983; Krashen, 1989).

Prior knowledge of a topic may also relate to students' use of support tools (Belland & Drake, 2013) and, hence, play a role in their use of auditory support. For example, Leslie and colleagues (2012) have shown that for students who already master knowledge on a topic, an audiovisual presentation does not have added value compared to a spoken-only presentation. However, for students with no prior knowledge on the topic, adding visual information can support them to make sense of the auditory explanation. Other studies also show that students

with low prior knowledge gain more advantage from audiovisual presentations, while students with high prior knowledge do not (Mayer & Gallini, 1990; Mayer, Steinhoff, Bower, & Mars, 1995). From their meta-analysis, Adesope and Nesbit (2012) also conclude that students with low prior knowledge are likely to learn more from verbally redundant material than those with high prior knowledge. Thus, whether or not information is redundant is also determined by a student's expertise, also known as the expertise reversal effect (Kalyuga, 2007; Kalyuga, Ayres, Chandler, & Sweller, 2003; Leslie et al., 2012). Likewise, students' time-on-task, indicating the amount of time a student is engaged in a certain activity (Berliner, 1990), is an important predictor to consider: research has consistently shown that time-on-task is positively related to students' learning as well as achievement (Snow, 1990; van Gog, 2013). Moreover, the amount of time a student needs to complete a task or master a skill largely depends on individual differences (van Gog, 2013).

Finally, students' background characteristics, such as their gender and socio-economic status (SES), also need to be considered to determine if these play a significant role in the use of TTS (Chang et al., 2011). More specifically, studies have already indicated that these characteristics can affect processes related to listening comprehension (Seright, 1985; Rubin, 1994).

3. Research purpose

CBLEs offer great potential to enrich students' learning process through different support tools. However, little is known about what kind of supports work best for various groups of students (Dalton & Strangman, 2006). Moreover, research on the use of TTS in CBLEs, and more specifically giving auditory support in language minority students' home language, is still very limited. Furthermore, few studies on the use of instructional supports in CBLEs and the related characteristics focus on students in primary education (Witteman & Segers, 2010).

The aim of the present study is to examine factors related to fifth-grade students' use of bilingual TTS in a CBLE focused on science education. Therefore, we will explore the use of TTS provided to students in two different languages (i.e., the LOI and one other language). Moreover, we will examine student characteristics that are related to the use of bilingual TTS. Therefore, the following research question guides the study: do student characteristics regarding their home language, the LOI, background, and learning achievement relate to the use of bilingual auditory support in a CBLE with TTS technology?

4. Method

4.1 *The CBLE E-Validiv*

E-Validiv (Author citation, 2016c) is a CBLE, developed as part of the broader Validiv-project (Valorizing Linguistic Diversity in Multiple Contexts of Primary Education), aimed at fourth- and fifth-grade students. It consists of eight different themes within the domain of science education (e.g., nature, geography, the human body), which are refined in various subthemes. Every subtheme offers information on a certain topic and gives the opportunity to practice the newly acquired content through a variety of exercises.

What makes this CBLE unique, is its multilingual character: all content is available in seven languages, namely Dutch, English, French, Italian, Spanish, Polish, and Turkish. A student always has access to two languages: the LOI (i.c., Dutch) and one of the six other languages. The other language is fixed according to a student's linguistic background or preference. For example, a student who speaks Turkish at home can go through E-Validiv in the LOI and Turkish. For language majority students and language minority students whose home language is not available in E-Validiv, the other language is most often set to French or English, as these are the first two languages students encounter in foreign language education.

As shown in Figure 1, different support tools are available in E-Validiv. First, the language switch button gives students the opportunity to switch between screens, thereby giving them access to exactly the same content in both languages. This ‘systematic alternating use of two languages or language varieties within a single conversation or utterance’ (Liebscher & Dailey-O’Cain, 2005, p. 235) reflects code-switching, a practice which is often used by bilinguals. Second, a digital notebook encourages students to select and write down the main ideas from the text in the language they choose. Third, the pedagogical agent in the form of a parrot guides students throughout the subtheme, offers explanations, and gives feedback. Fourth, the arrow allows students to enter the following screen, covering additional information or exercises. Students have access to the different support tools, regardless of their proficiency in the home language or the LOI. They can decide when and why they want to employ support in one of both languages.

The support tool in E-Validiv which is the focus of this study is the availability of TTS technology: all the content which is written on the screen can also be read aloud, thereby giving students access to both languages in the visual and auditory modality. Whenever a student shifts to a next page, TTS automatically starts in the currently selected language. When a student switches to the other language and returns, TTS is picked up where the student left off. Students can also choose to pause or replay TTS through a button, thereby giving them control of the pacing of TTS (cf. Moreno & Mayer, 2007). As technology offers the possibility to track and analyze students’ use of support tools and relate it to student characteristics (Dalton & Strangman, 2006), logfiles were set up to save students’ relevant actions in E-Validiv.

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4.2 Participants

In total, 360 fifth-grade students (mean age=11.21 years; 54.1% girls; 45.9% boys) from 31 classrooms in 23 schools participated in the study. The schools were situated in Flanders (Belgium), in which three regions with relatively diverse linguistic populations were selected. Within these regions, 214 primary schools were randomly selected and contacted to participate in the Validiv-project; 31.30% of them decided to join the project. In half of the participating schools, fifth-grade students got access to the CBLE E-Validiv.

4.3 Procedure

At the beginning of the project, two researchers visited all the participating schools. During regular classroom periods of three times 50 minutes, students completed a reading comprehension test, a science achievement test, and a paper-and-pencil questionnaire concerning background characteristics. The questionnaire addressed what languages the students speak at home, their self-assessed proficiency in their home language, gender, socioeconomic status (SES), and the use of linguistic resources in the LOI and the other language. One of both parents also filled in a paper-and-pencil questionnaire at home, which asked for the professional occupation of both parents, whether the home language was different from the LOI and which different languages were used at home.

All participating students had access to E-Validiv during one school year with a personal user name and password. They had already gained experience with the CBLE in the former school year. Logfiles were used to trace students' activities throughout the CBLE. From the moment they were logged in, all their relevant actions were registered and saved, for example the time they dedicated to TTS in both the LOI and the other language.

4.4 Measures

Dependent variables. Regarding the time dedicated to TTS in both languages, the duration of TTS in both the LOI and the other language was extracted from the logging. To take into account the complete time dedicated to TTS, we opted to convert the absolute duration of TTS to a relative duration in the form of percentages. Hence, the total amount of time directed to TTS is distributed between a percentage of time directed to TTS in the other language and a percentage of time directed to TTS in the LOI, together comprising 100% of time dedicated to TTS.

Explanatory variables at student level. Student status in E-Validiv distinguishes language minority students for whom the other language is their home language and language majority students for whom the other language is a foreign language. Students indicating that they sometimes, often or always speak another language with at least one of their parents were considered as language minority students. Next, they were asked which language they speak at home with their parents. This was linked to the language available to them in E-Validiv. If students indicated the same language as the one available to them in E-Validiv, they were considered as language minority students for whom the other language is their home language. Students who indicated that they always or mostly speak Dutch with both of their parents were considered as language majority students. The variable on the other language in E-Validiv refers to the language students can access in the CBLE, next to the LOI. This information was obtained through the logging. The time-on-task in E-Validiv was extracted from the logging and gives the total amount of time students have spent on E-Validiv during one school year.

To measure students' self-assessed proficiency in their home language, they were asked to what extent they can understand, speak, read, and write in their home language by giving a score on a five-point Likert-scale (1=very poor; 5=very strong). A mean score was calculated

for the four skills. Language minority students first had to answer what two other languages they know, next to the LOI. If one of these languages was consistent with the other language available to them in E-Validiv and if it was consistent with a language one of both parents had identified as being most proficient in, it was considered as the student's home language. For language majority students, their score on the self-assessed proficiency in the LOI was considered as these students use the same language at home as the LOI. Students' self-assessed proficiency in the LOI was also determined by means of a mean score on the extent to which they can understand, speak, read, and write in the LOI, measured by a five-point Likert-scale (1=very poor; 5=very strong).

To determine family SES, the international socioeconomic index of occupational status (ISEI08) was measured, with a score from 0 to 100 (Ganzeboom, de Graaf, & Treiman, 1992). Both students and their parents were asked about the professional occupation of both parents. Parents' answers were used as reference; when parents did not fill in the questionnaire, students' answers were used.

The use of linguistic resources in the LOI was measured by means of two questions, namely "How often do you read a book in Dutch?" and "How often do you watch television in Dutch?". Students had to answer on a five-point Likert-scale (1=never; 5=every day); the mean score for both was calculated. The same procedure was followed to determine the use of linguistic resources in other languages.

A science achievement test was used as a measure for prior knowledge. The test was based on the released 2003 Dutch science items from The International Mathematics and Science Study (TIMSS) (Brusselmans-Dehairs & Valcke, 2004). Students had to answer 34 multiple-choice items regarding earth science, life science, and physics. The answers were binary coded, with a maximum score of 34 points.

Reading performance was measured by means of a reading comprehension test, based on the reading comprehension test from the Dutch Institute for Test Development (Cito) (Staphorsius & Krom, 1998). Students had to answer 20 multiple-choice questions about three fictional texts. They could achieve a total score of 20 points as the answers were binary coded.

4.5 Data Analysis

The relationship between student characteristics and students' use of the bilingual TTS in E-Validiv was analyzed through multilevel hierarchical regression analyses (MLwiN 2.32). This approach was chosen as the data have a clear hierarchical structure: 360 students (level 1) are nested within 31 classrooms (level 2).

First, a fully unconditional null model was tested to examine whether a multilevel approach was justified. Student characteristics related to the use of E-Validiv, their home language, background characteristics, characteristics regarding the use of linguistic resources in the LOI and other languages, and characteristics regarding learning achievement were integrated. It was also considered to enter classroom characteristics regarding the proportion of language minority students in the classroom¹ and the way the classroom teacher deals with the linguistic diversity present in the classroom². However, due to a high number of missing values on both of these variables, they were not taken into account in the estimation of the models. Parameters were estimated through the iterative generalized least squares algorithm.

¹ To measure the proportion of language minority students, it was determined how many students in the classroom have a home language other than the LOI (cf. Explanatory variables at student level). This number of students was divided by the total number of students in the classroom.

² All students' classroom teachers completed a questionnaire, which asked about the ways in which they approach the present linguistic diversity in their classroom practice. Therefore, they had to answer four items on a five-point Likert scale (1 = never; 5 = very often), asking whether students are allowed to use a language other than the LOI to (1) explain something to a peer, (2) during group work, (3) in the classroom, and (4) on the playground. A mean score was calculated for the answer on the four items.

The model fit could be determined through calculating the difference in deviance between two consecutive models.

5. Results

5.1 Descriptive results of students' proportion of time dedicated to bilingual TTS

Table 1 offers an overview of the means, standard deviations, and Pearson' bivariate correlations for the variables under study. Table 2 gives the descriptive results regarding students' general use of TTS in both the LOI and the other language. The results are also split up according to students' status in E-Validiv, with a distinction between language minority students who have their home language available and language majority students for whom the other language is a foreign language.

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5.2 Multilevel analysis for the proportion of time dedicated to bilingual TTS

Table 3 gives a summary of the stepwise multilevel approach with all model estimates for the proportion of time dedicated to TTS in the other language³. First, a fully unconditional two-level null random intercepts model with the proportion of time dedicated to TTS in the other language as response variable was estimated. The null model does not contain any explanatory variable yet. The intercept of the null model indicates the overall mean proportion for the time dedicated to TTS in the other language (M=18.670) for all students across all

³ For reasons of conciseness, we have not included the table with model estimates for the proportion of TTS duration in the LOI: as proportions are used, these results give the exact opposite of the results for TTS in the other language. Moreover, although seven models were tested for this study, we only report on the results for the null model and the final model here. For an overview of all estimated models, we refer to Table 3.

classrooms. The results confirm that a multilevel approach is justified as the random part of Model 0 reveals that the variances at both classroom level ($\sigma^2_{u0}=149.089$, $\chi^2=9.412$, $df=1$, $p<.01$) and student level ($\sigma^2_{e0}=393.856$, $\chi^2=164.804$, $df=1$, $p<.001$) are significantly different from zero. Whereas 72.5% of the variance of time dedicated to TTS in both languages can be explained by differences between students within classrooms, 27.5% is due to differences between classrooms. By introducing additional variance at classroom level, the two-level null random intercepts model is a significant improvement over the single-level model ($\chi^2=61.807$, $df=1$, $p<.001$).

In the following steps, the characteristics regarding the use of E-Validiv (i.e., student status in Model 1, other language in Model 2, time-on-task in Model 3), the home language (i.e., self-assessed proficiency in the home language in Model 4), general background characteristics (i.e., gender and SES in Model 5), characteristics related to the use of linguistic resources (i.e., linguistic resources in LOI and other languages in Model 6), and learning achievement (i.e., science achievement and reading performance in the LOI in Model 7) were consecutively added.

The final Model 7 has an intercept of 7.543, which indicates the overall mean of the proportion of time spent on TTS in the other language for girls for whom the LOI is their home language, who have E-Validiv available in the LOI and a foreign language, namely English, and who have an average score on time-on-task in the CBLE, self-assessed proficiency in their home language, SES, the use of linguistic resources in the LOI and other languages, science achievement, and reading performance in the LOI.

Regarding the characteristics related to the use of E-Validiv, language minority students for whom the other language is their home language use TTS significantly more in their home language than language majority students for whom the other language is a foreign language ($\chi^2=20.439$, $df=1$, $p<.001$). Neither the other language available in E-Validiv (French:

$\chi^2=0.067$, $df=1$, $p>.05$; Italian: $\chi^2=0.272$, $df=1$, $p>.05$; Polish: $\chi^2=0.308$, $df=1$, $p>.05$; Spanish: $\chi^2=0.764$, $df=1$, $p>.05$; Turkish: $\chi^2=2.378$, $df=1$, $p>.05$) nor time-on-task ($\chi^2=0.266$, $df=1$, $p>.05$) significantly contribute to the model.

Self-assessed proficiency in the home language is positively related to the use of TTS in the other language ($\chi^2=15.560$, $df=1$, $p<.001$), whereas the general background characteristics (gender: $\chi^2=1.510$, $df=1$, $p>.05$; SES: $\chi^2=1.540$, $df=1$, $p>.05$) and the characteristics related to learning achievement (science achievement: $\chi^2=0.390$, $df=1$, $p>.05$; reading performance in the LOI: $\chi^2=0.570$, $df=1$, $p>.05$) do not make a significant contribution to the model. Finally, the use of linguistic resources in the LOI is negatively related to the use of TTS in the other language ($\chi^2=8.577$, $df=1$, $p<.01$); the use of linguistic resources in other languages does not play a role for the use of bilingual TTS ($\chi^2=2.107$, $df=1$, $p>.05$).

The final Model 7 has a better model fit than the two-level null random intercepts model, as the difference in deviance between both models is significant ($\chi^2=741.907$, $df=14$, $p<.001$). The comparison of models and model fit measures for the consecutive models can be found in Table 3.

<< Please insert Table 3 about here >>

6. Discussion and conclusion

6.1 Discussion

TTS is a promising means to support knowledge acquisition in CBLEs for students in general, and language minority students in particular. However, the research on TTS and the characteristics related to its adoption is still limited. Therefore, we aimed to determine students' use of bilingual TTS in a CBLE and student characteristics related to this use.

Language minority students who have access to their home language in the CBLE use TTS more in their home language, compared to language majority students for whom the other language is a foreign language. This is in line with studies indicating that particularly language minority students may get assistance from the access to auditory support, next to on-screen text (Adesope & Nesbit, 2012; Kalyuga, 2012). Nevertheless, language minority students still use TTS mostly in the LOI, which implies their main focus remains on the content in the LOI. This indicates that language minority students strategically appeal to their home language, namely to support their learning process in the LOI by strengthening understanding through their home language (Sierens & Van Avermaet, 2014; Author citation, 2016a, 2016b). As they often only use their home language in a spoken way, the auditory support, next to the on-screen text, can assist them in overcoming barriers with reading in their home language. Hence, they can get a stronger grip on the written content and focus more on meaning construction (Dalton & Strangman, 2006; Lundberg & Olofsson, 1993; Proctor et al., 2007). This is in line with the Cognitive Theory of Multimedia Learning (Mayer, 2010) and is confirmed in Author (2016b) on the CBLE E-Validiv. Moreover, the strong focus on the LOI can help language minority students to become more highly proficient in literacy in the LOI, as oral language development is crucial, next to reading (August & Shanahan, 2006).

Furthermore, language majority and language minority students who assess themselves as less proficient in their home language (respectively Dutch or another language) employ TTS more in the LOI, compared to students with a high self-reported proficiency in their home language. This is in line with the findings from Author (2016b), which indicate that language minority students seldom switch to the content in their home language because of their assumed weak proficiency in this language. However, research has already shown that students with a low level of proficiency in a certain language indeed benefit from learning

with a combination of on-screen text and auditory support (Chang et al., 2011; Montali & Lewandowski, 1996; Mueller, 1980), for example to compensate for things not understood in written form or vice versa (Adesope & Nesbit, 2012). As students with a low self-assessed proficiency in their home language seem to feel less confident in applying the auditory support offered to them, special attention should be given to this group. According to Proctor and colleagues (2007), some supports in CBLEs need to be “pulled” by students while others need to be “pushed” to students. The latter certainly needs to be considered for less successful students, as they often not apply the opportunities offered to them, even if they would profit from using them (Clarebout, Elen, Johnson, & Shaw, 2002; Proctor et al., 2007).

The access to and use of linguistic resources in the LOI is also related to students’ use of bilingual auditory support. Students who read more books and watch more television in Dutch, the LOI, apply TTS more in the LOI. As the use of these linguistic resources has shown to contribute to vocabulary development (e.g., Leppänen et al., 2005), text comprehension (e.g., Guthrie et al., 2001; Webb & Rodgers, 2009), and general knowledge (e.g., Cox & Guthrie, 2001), students may feel most confident in applying TTS in the LOI.

The other characteristics examined in this study do not seem to lead to a distinct use of the bilingual auditory support. For example, reading performance in the LOI nor reading books or watching television in other languages explain differences in the use of the bilingual auditory support. Although prior research has indicated that students with low prior knowledge profit more from audiovisual presentations (Leslie et al., 2012; Mayer & Gallini, 1990; Mayer et al., 1995), in this study, high or low prior knowledge on science topics does not lead to a distinct use of auditory support. Furthermore, boys and girls approach the bilingual TTS in a similar way, just like students with different socioeconomic backgrounds. Moreover, although the results indicate differences at classroom level, these could not be examined, due to a too high number of missing values on classroom variables.

6.2 *Limitations and future directions*

This study's limitations offer opportunities for future research. First, students assessed the proficiency in their home language themselves. We were not able to integrate other measures for this factor, due to the large linguistic diversity of our sample and the lack of standardized tests (cf. Rubin, 1994). Second, future studies using qualitative methods (e.g., observations, interviews, think-aloud, stimulated recall) can shed more light on what students are attending to and what their motives are to use the auditory bilingual support at a certain moment. Third, as classroom differences have been determined, future studies could take into consideration classroom aspects, such as the ways in which teachers have stimulated students to use the functionality of TTS or the extent to which content in E-Validiv is connected to the broader classroom practice. Finally, future studies can focus on how the use of the CBLE is related to students' achievement. However, it will continue to be important to integrate measures of students' use of support tools (Laufer, 2003) and factors related to this use by different groups of students, as it cannot be assumed that the integrated support tools in a CBLE have a similar impact on every student (Belland & Drake, 2013). This study has contributed to this by revealing student characteristics which are related to students' use of bilingual TTS.

Some considerations can also be made for the further development of CBLEs integrating TTS technology, and more specifically bilingual auditory support. First, it can be examined whether more choice options should be built in CBLEs to accommodate to students' needs and preferences, thereby giving them more degrees of freedom to shape their own learning process (Türk & Erçetin, 2014). In the CBLE under study, TTS in either language starts automatically from the moment a student enters a new screen. Although the student can pause and replay TTS, it is not possible to only listen to a fragment of the on-screen text. Moreover, providing options of visual and verbal input so that students have access to multiple representations and can request the information they need, can lead to students actively

selecting and processing the information they prefer (Plass et al., 1998, 2003). Taking into account individual differences among learners is crucial for the development of adaptive CBLEs. Second, more flexibility should be considered regarding the speech rate and voice of TTS (e.g., Dalton & Proctor, 2007). Letting students control the speech rate so that they can accommodate it to their personal needs can improve listening comprehension and thus help in constructing meaning (Zhao, 1997). For example, different students who had Turkish available in E-Validiv signaled that the speech rate in Turkish was too high. As a result, they switched more quickly to the content in the LOI. Finally, students should be assisted by the teacher to get to know the possibilities offered in the CBLE and how to use them. By discussing together in what way and when different support tools can be appealed to, TTS can be used optimally as a true support tool for learning.

6.3 Conclusion

This study advances the understanding of how students from different linguistic backgrounds use bilingual TTS in a CBLE. It particularly broadens insights into language minority students' use of TTS in their home language. Embedded support tools are a characteristic feature for most CBLEs. The findings from the present study help to advance the design of effective computer-based learning environments which appeal to students' personal needs and prepare them to use various support tools in a strategic way to serve their own learning goals (Proctor et al., 2007). CBLEs like E-Validiv offer a promising pathway to help bridge the achievement gap between language minority students and language majority students by offering language minority students support in their home language, both in the visual and auditory modality.

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Author citation. (2014).

Author citation. (2016a).

Author citation. (2016b).

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FACTORS RELATED TO BILINGUAL TEXT-TO-SPEECH

Table 1. Descriptive statistics and Pearson's bivariate correlates

	M(SD)	1	2	3	4	5	6	7	8	9	10	11	12
1. Student status in E-Validiv (ref. cat. LMa students)	-	1											
2. OL in E-Validiv	-	.47***	1										
3. Time-on-task	149.11(94.00)	.09	.05										
4. Proficiency HL	4.29(0.67)	-.40***	-.13*	-.05	1								
5. Gender	-	.02	-.01	.02	.05	1							
6. SES	50.84(21.41)	-.29***	-.39***	-.04	.07	.04	1						
7. Linguistic resources LOI	4.02(0.89)	-.16**	-.07	.11	.05	-.09	.06	1					
8. Linguistic resources OL	2.88(1.23)	.57***	.26***	.09	-.08	.00	-.12*	.01	1				
9. Science achievement LOI	21.45(5.07)	-.40***	-.29***	.00	.16**	.05	.45***	.16**	-.28***	1			
10. Reading performance LOI	12.25(5.07)	-.42***	-.28***	.00	.22***	-.10	.38***	.20***	-.33***	.65***	1		
11. TTS OL	18.55(23.19)	.28***	.08.	.08	.04	.11*	.00	-.13*	.25***	-.07	-.06	1	
12. TTS LOI	81.45(23.19)	-.28***	-.08	-.08	-.04	-.11*	.00	.13*	-.25***	.07	.06	---	1

*p<.05, **p<.01, ***p<.001.

Note: M=mean; SD=standard deviation; LMa=language majority; OL=other language; HL=home language

FACTORS RELATED TO BILINGUAL TEXT-TO-SPEECH

Table 2. Mean and standard deviation for proportion of duration of TTS

	Proportion of duration of TTS	
	In other language	In language of instruction
	M (SD)	M (SD)
General	18.55 (23.19)	81.45(23.19)
LMi students (n=231)	23.43(26.41)	76.57 (26.41)
LMa students (n=129)	9.80 (11.57)	90.20 (11.57)

Note: M=mean; SD=standard deviation; LMi=language minority; LMa=language majority

FACTORS RELATED TO BILINGUAL TEXT-TO-SPEECH

Table 3. Unstandardized regression coefficients and standard errors from the random intercept model (dependent variable: proportion of duration of TTS in OL)

	Single level	Model 0	Model 1	Model 2	Model 3
<i>Fixed part</i>					
Intercept(cons)	18.547(1.220)***	18.670(2.499)***	10.388(3.002)***	9.893(3.160)**	9.857(3.167)**
Student level					
Student status E-Validiv (ref. cat.: LMa students)			12.333(2.706)***	13.850(3.250)***	13.828(3.249)***
OL in E-Validiv					
French				-1.052(3.259)	-1.079(3.258)
Italian				5.787(5.181)	5.861(5.179)
Polish				-4.862(11.958)	-5.005(11.952)
Spanish				10.192(6.316)	10.106(6.312)
Turkish				-3.090(4.113)	-3.161(4.114)
Time-on-task					-0.010(0.016)
Proficiency HL					
Gender (ref. cat.: girl)					
SES					
Linguistic resources LOI					
Linguistic resources OL					
Science achievement LOI					
Reading performance LOI					
<i>Random part</i>					
Classroom level		149.089(48.596)**	134.821(44.569)**	120.467(40.900)**	121.824(40.904)**
σ^2_{u0} (between)					
Student level σ^2_{e0} (within)	536.058(39.955)***	393.856(30.680)***	373.561(29.086)***	369.575(28.759)***	368.902(28.728)***
<i>Model fit</i>					
Deviance(-2LL)	3283.963	3222.156	3201.979	3195.737	3195.382
χ^2		61.807	20.177	6.242	0.355
df		1	1	5	1
p		***	***		
Reference model		Single level	Model 0	Model 1	Model 2
<i>Variance at level 2</i>					
$\rho(\%)$	27.5	26.5	24.6	24.8	31.1

*p<.05, **p<.01, ***p<.001.

Note: values in parentheses are standard errors; LMa=language majority; OL=other language; HL=home language

FACTORS RELATED TO BILINGUAL TEXT-TO-SPEECH

Table 3. Unstandardized regression coefficients and standard errors from the random intercept model (dependent variable: proportion of duration of TTS in OL)
(continued)

	Model 4	Model 5	Model 6	Model 7
<i>Fixed part</i>				
Intercept(cons)	6.644(3.288)*	4.858(3.587)	7.078(3.729)	7.543(3.781)*
Student level				
Student status E-Validiv (ref. cat.: LMa students)	21.782(3.645)***	21.116(3.680)***	18.402(3.998)***	18.190(4.023)***
OL in E-Validiv				
French	-1.385(3.354)	0.268(3.358)	-0.402(3.337)	-0.881(3.412)
Italian	2.606(5.120)	3.388(5.010)	3.086(4.910)	2.586(4.962)
Polish	-6.952(11.270)	-5.070(11.101)	-5.940(10.891)	-6.067(10.930)
Spanish	5.203(6.408)	8.077(6.482)	6.425(6.533)	5.790(6.626)
Turkish	-9.302(4.342)*	-7.562(4.422)	-6.515(4.419)	-6.938(4.499)
Time-on-task	0.004(0.016)	0.003(0.017)	0.006(0.017)	0.009(0.017)
Proficiency HL	7.637(1.743)***	7.877(1.727)***	7.154(1.781)***	7.133(1.808)***
Gender (ref. cat.: girl)		3.198(2.076)	2.702(2.091)	2.639(2.147)
SES		0.051(0.058)	0.063(0.058)	0.077(0.062)
Linguistic resources LOI			-3.837(1.266)**	-3.782(1.291)**
Linguistic resources OL			1.637(1.135)	1.711(1.179)
Science achievement LOI				-0.195(0.312)
Reading performance LOI				-0.020(0.291)
<i>Random part</i>				
Classroom level	141.312(46.255)**	168.514(53.618)**	167.145(53.099)**	170.165(54.011)**
σ^2_{u0} (between)				
Student level σ^2_{e0} (within)	313.591(26.415)***	296.983(25.325)***	281.903(24.781)***	283.281(25.048)***
<i>Model fit</i>				
Deviance(-2LL)	2728.022	2655.986	2504.187	2480.249
χ^2	467.36	72.036	151.799	23.938
df	1	2	2	2
p	***	***	***	***
Reference model	Model 3	Model 4	Model 5	Model 6
<i>Variance at level 2</i>				
$\rho(\%)$	36.2	36.2	37.2	37.5

*p<.05, **p<.01, ***p<.001.

Note: values in parentheses are standard errors; LMa=language majority; OL=other language; HL=home language

Figure 1: Screenshot of a page within E-Validiv with integrated tools