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Use of Technology as an Innovative Approach to Non-Linguistic Cognitive Therapy

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Abstract: The relationship between cognitive abilities and linguistic competencies in children has been documented, with multiple studies demonstrating that subtle cognitive weakness can contribute to language learning difficulties. Furthermore, recent research has revealed that cognitive intervention can improve the linguistic abilities of children who have a primary language impairment (PLI). This progression in communication function would be due to improved access to stored information. The goal of this article is to discuss how the use of technology such as the iPad and its plethora of relevant applications (apps), could be a useful tool within the non-linguistic cognitive approach. Moreover, a new model of language intervention using technology to increase cognitive skills has been proposed. Applications designed to increase working memory, sustained attention, and processing speed are increasingly available. Since many of these apps are available as games, they offer promising results due to their motivating characteristic, as much for the children using them as for their parents looking for a new method of treatment. This innovative approach could produce positive results; even improve children's language skills more rapidly than traditional approaches.

Keywords: Technology, Cognition, Primary Language Impairment (PLI)

Introduction

There is growing evidence to support the fact that cognitive and linguistic skills are correlated in children (e.g., Ebert and Kohnert 2009; Kohnert and Ebert 2010). There is also evidence that children with primary language impairment (PLI) achieve lower scores than their peers on non-linguistic cognitive processing tasks, although they do not necessarily score below the norm (Amitay, Ahissar, and Nelken 2002; Archibald and Gathercole 2006; Bishop 1996; Evans and Pourcel 2009; Ellis Weismer, Evans, and Hesketh 1999; Gathercole and Baddeley 1990; Gathercole et al. 1994; Kohnert, Windsor, and Dongsun 2006; Leonard 1998; Montgomery and Evans 2009; Tallal 2003; Thordardottir et al. 2011; Ullman and Pierpoint 2005). Essentially, a certain level of cognitive abilities is needed for children to learn language. Cognitively demanding experiences can modulate brain development and, by the same token, modify cognitive functions (Green and Bavelier 2003; Maguire et al. 2000; Polk and Farah 1998; Salthouse and Mitchell 1990). This being said, the use of cognitive tasks could indirectly improve language skills. In fact, studies (e.g., Ebert and Kohnert 2009; Ebert, Rentmeester-Disher, and Kohnert 2012) have already shown that language skills can be improved by working on cognitive processing skills. For bilingual children, the advantage of a non-linguistic cognitive approach is amplified, since this method was shown to have positive effects in both languages in a study by Ebert, Rentmeester-Disher, and Kohnert (2012).

According to Rosas et al. (2003), "*the future of portable technology as an instructional tool – such as a video game – is promising* (p. 91)". Many conventional cognitive games are now available in an application or "app" format, and can be used on Apple devices such as the iPad (Apple 2013) or other Android tablets. Since some studies have shown that playing video games may lead to superior spatial resolution of visual processing, presumably because of the practice they obtained while playing the games (Green and Bavelier 2003), the use of technology to play cognitively steered games could be a new approach to non-linguistic cognitive processing therapy. Not only could it be beneficial for improving monolingual children's language skills but also for improving the learning of both languages in bilingual children. This method might prove to be at the same time motivating for children and cost effective as it could reduce the overall length of therapy needed. The use of technology such as an iPad or other tablet, and cognitively steered apps,

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could consequently become an innovative approach to the treatment of PLI. The aim of this article is to propose a model that encompasses the use of technology for the purpose of non-linguistic cognitive intervention, for both monolingual and bilingual children who have PLI. The proposed model could be used as an experimental design for future studies to support the hypothesis that technology combined with non-linguistic cognitive intervention is beneficial for children who have PLI.

Cognition and Language

Many authors maintain that children who have PLI also have reduced performances on cognitive tasks (e.g., Archibald and Gathercole 2007; Bishop and Norbury 2005; Gathercole 2006; Hoffman and Gilman 2004; Im-Bolter, Johnson, and Pascuale-Leone 2006; Ellis Weismer et al. 2005). Indeed, according to the *General interactive processing theory*, basic cognitive mechanisms are inherent in the acquisition and effective use of language skills (Kohnert 2007).

As previously mentioned, numerous studies have shown that certain non-linguistic capacities are compromised in children who have PLI. These non-linguistic abilities include sustained attention (e.g., Spaulding, Plante, and Vance 2008; Finneran, Francis, and Leonard 2009), working memory (Archibald and Gathercole 2006; Bishop 1996; Ellis Weismer et al. 1999; Gathercole et al. 1994; Kohnert, Windsor, and Dongsun 2006; Leonard 1998; Montgomery and Evans 2009; Tallal 2003; Ullman and Pierpoint 2005), phonological working memory (Archibald 2006; Bishop 1996; Bishop et al. 1999; Wager, Smith, and Jonides 2003), executive control (Baddeley, Gathercole, and Papagno 1998; Baddeley 1996; Bishop and Norbury 2005; Ullman and Pierpoint 2005), discrimination of non-verbal components (Amitay, Ahissar, and Nelken 2002; Tallal and Piercy 1973), procedural memory and abstraction (Evans and Pourcel 2009), processing speed (Catts, Adlof, and Ellis Weismer 2006) and auditory treatment (Tallal 2003), among others. Children with PLI also have difficulty processing information when the complexity of tasks increase, which has been given the term *limited processing capacity* (*LPC*) (Ellis Weismer, Evans, and Hesketh 1999; Gathercole 2006; Leonard et al. 2007; Miller et al. 2001; Montgomery and Windsor 2007). The presence of subclinical weaknesses of processing speed, working memory and attention in children with PLI could contribute to language deficits by impeding language learning (e.g. Ebert, Rentmeester-Disher, and Kohnert 2012; Kohnert and Ebert 2010; Leonard et al. 2007).

According to Petitto (2009), extensive exposure to more than one language at an early age positively impacts language development. Indeed, according to this author, brain imaging research support early exposure to second language mastery. Studies using functional Near Infrared Spectroscopy (fNIRS) have demonstrated that early exposure to two languages modifies the organization of language in the brain, which has been named the “bilingual signature” (e.g., Kovelman, Baker and Petitto 2008; Kovelman, Shalinsky, Berens and Petitto 2007).

Primary Language Impairment (PLI)

It is estimated that 7 % of school-aged children have a language impairment (Tomblin et al. 1997). These children typically have a persisting language delay (American Psychiatric Association 1994; Bishop 1992; Leonard 1998). Within a clinical setting, the term primary language impairment (PLI) defines language learning difficulties in the absence of other developmental difficulties (Kohnert 2010; Tomblin et al. 2003), which suggest that the difficulties occur mainly within the language domain, without implying that treatment of information or working memory difficulties could not be co-existent.

Children with PLI do not have a specific lesion site, nor are their language delays caused by a clear cognitive impairment (Kohnert, Windsor, and Ebert 2009). However, new findings support the possibility of a neurological component to PLI (see Ullman and Pierpont 2005 for a review). According to Kohnert (2010), PLI is due to innate factors that negatively interact with the demands of language-learning. Some of the reported markers of PLI are limited vocabulary (e.g., Gray 2004; Rescola 2005), morphosyntaxical difficulties (e.g., Bedore and Leonard 2001; Cleave and Rice

1997), shorter and less complex narrative discourse (e.g., Gutiérrez-Clellen 2004; Mayer-Crittenden 2013; Scott and Windsor 2000), and difficulties with social language (Fujiki et al. 1999). Children with PLI are also at risk for reading and writing difficulties (Bishop and Snowling 2004). This will in turn put them at risk for reduced academic, economic, and social outcomes (Kohnert 2010). Until recently, children with a language impairment were thought to have intact cognitive skills (Leonard 1998). We now know that children with PLI may have general processing capacity limitations which lead to a reduced performance in both the verbal and nonverbal areas (Leonard et al. 2007; Miller et al. 2001; Weismer and Hesketh 1996).

Working Memory

Working memory is a limited system responsible for the temporary classification and the treatment of information (Baddeley 1986; Just and Carpenter 1992). Working memory was defined by Baddeley and Hitch (1974) as an active memory system which handles both the maintenance of short-term information and processing for the transition to the long-term memory, allowing the realization of immediate cognitive activities. Baddeley and Hitch (1974) initially proposed three components of working memory: the central executive, the visual spatial sketchpad and the phonological loop. In 2000, a fourth component was added to the model, the episodic buffer (Baddeley 2000).

The central executive is a core element of Baddeley’s model. It is responsible for the control and regulation of cognitive processes, and could even be considered as a surveillance system (Baddeley and Della Sala 1996). The visual spatial sketchpad specializes in the maintenance and handling of visual and spatial representations (Alloway, Gathercole, and Pickering 2006; Baddeley and Logie 1999). There are two components in the visual spatial sketchpad: one that specializes in visual information and the other that specialized in spatial information (Logie 1995). The phonological loop on the other hand provides a temporary storage of verbal information (Alloway, Gathercole, and Pickering 2006; Baddeley and Logie 1999). It plays an important role in subvocal rehearsal, which is important in the prevention of degradation of verbal information (Baddeley and Hitch 1974). The phonological loop is also implicated in vocabulary acquisition, particularly in the preschool years (Baddeley, Gathercole, and Papagno 1998). The last component, the episodic buffer, has a direct relationship with long-term memory, which could be important for learning (Pickering and Gathercole 2004). It uses multidimensional codes to incorporate representations of working memory and long-term memory into unitary episodic representations that could correspond to conscious experiences (Pickering and Gathercole 2004).

Sustained Attention

Attention is a cognitive process that allows for the concentration on a stimulus or an event (Ashcraft and Klein 2006). Without attention, the cognitive system has difficulty operating (Ashcraft and Klein 2006). In fact, attention impairments have an impact on all cognitive abilities (Sarter and Bruno 1999). Krakow et al. (1983) describe sustained attention as the ability to become and to remain engaged. It can also be defined as a process where a person needs to mindfully and consciously process stimuli, whose non-arousing qualities will otherwise lead to habituation and distraction (Robertson et al. 1997). It represents a fundamental factor in human cognitive capacity (Sarter et al. 2001). Sustained attention is needed to accomplish all cognitive activity and all thoughts (Zarghi et al. 2011). Indeed, Matthews et al. (2010) state that it is crucial for human performance. According to DeGangi and Porges (1990), sustained attention contains three steps: obtaining attention, retaining attention and releasing attention. It requires a conscious effort that is activated in about 300 ms (Yeshurun, Montagna, and Carrasco 2007). Sustained attention does not vary according to gender, but does improve with age (Seidel and Joschko 1990). However, Sarid, and Breznitz (1997) state that sustained attention improves between the ages of two and four, but reaches a plateau after the age of four.

Many factors impact sustained attention (Parasurmaman 1986; Parasuraman, Warm, and Dember 1987). Among them are the successive presentation of signal and non-signal features, high event rate, spatial uncertainty about the locus of event presentation, the use of dynamic stimuli, demands on working memory and using signals with conditioned or symbolic significance (Sarter, Givens, and Bruno 2001). Fatigue and stress can also cause difficulties in sustained attention (Matthews et al. 2000), and in turn, tasks related to sustained attention can cause fatigue and stress (Warm, Matthews, and Finomore 2008).

Processing Speed

Children with PLI process information more slowly than typically developing children (Kohnert, Windsor, and Ebert 2009; Ullman and Pierpont 2005). For example, they are slower at processing linguistic tasks such as naming pictures, and making lexical judgments (Windsor et al. 2008). They are also slower at processing non-linguistic tasks such as mentally rotating geometrical shapes (Windsor et al. 2008). Children with PLI also have a slower response time when detecting pure tones that have a brief duration, when reproducing a series of colored lights, when tapping their fingers rapidly in response to stimuli, when moving pegs on a board, and when stringing beads (e.g., Bishop 1992; Johnston and Ellis Weismer 1983; Miller et al. 2001; Miller et al. 2006; Owen and McKinlay 1997; Powell and Bishop 1992; Tallal and Piercy 1974; Uwer, Albrecht and Von Suchodeletz 2002; Windsor et al. 2001).

Non-Linguistic Cognitive Therapy

For the treatment of cognitive skills to impact the language abilities of children with PLI, a correlation and a causal association are required between non-linguistic processing weaknesses and language skills (Ebert, Rentmeester-Disher, and Kohnert 2012). New studies have shown that it is possible to improve language learning in children who have PLI by working on cognitive non-linguistic processing tasks (e.g. Ebert and Kohnert 2009; Ebert, Rentmeester-Disher, and Kohnert 2012). In 2009, Ebert and Kohnert's study revealed that two children aged 7 and 8 with PLI made gains in expressive language skills after participating in activities targeting auditory memory and speed of processing for visual information. In 2012, Ebert, Rentmesster-Disher, and Kohnert revealed that two bilingual children (Spanish and English) made gains in cognitive non-linguistic processing skills as well as gains in language ability after participating in activities targeting processing speed and sustained attention. Given that cognitive processing deficits contribute to language learning delays in PLI, it is not surprising that the improvement of processing skills positively affects language learning (Ebert, Rentmeester-Disher, and Kohnert 2012). Since this treatment method does not target a specific language, gains can be made in both languages known to bilingual children (Ebert, Rentmeester-Disher, and Kohnert 2012).

Impact for Bilingual Children

Since both languages are affected in bilingual children with PLI (Kohnert 2010), they typically learn each one of them at a slower pace (Hakansson, Salameh, and Nettelbladt 2003). Non-linguistic cognitive therapy could be a very effective approach in the intervention of bilingual children. Since the cognitive gains made from this type of intervention increases skills in both languages of a bilingual child (Ebert, Rentmeester-Disher, and Kohnert 2012), a speech-language pathologist who has no or limited knowledge of the foreign language could assist in increasing linguistic skills within that language by using a cognitive non-linguistic treatment approach. Not only could this technique help improve the learning of a language unbeknownst to a speech-language pathologist, it could also improve skills within two languages at once, in turn reducing intervention time and costly dollars associated with extended treatment.

Use of Technology and Apps

The use of technology for educational purposes has grown over the years. Most schools are equipped with computers and software to help children learn, read and write. Many speech-language pathologists are also using new technology such as the iPad (Apple 2013) with applications designed for speech and language treatment. Since children are motivated by the use of technology (Kulik 1994; McFarlane, Sparrowhawk, and Heald 2002), an approach that incorporates it within a cognitive non-linguistic treatment could bring greater success than traditional approaches.

In their study, Ebert, Rentmesster-Disher, and Kohnert (2012) used tangible games such as *Blink* (Staupe 2001), which requires that children sort cards according to their shape, colour and the number of symbols; *Bop-it*, a game that requires children to perform actions according to the musical sounds they hear; and *Simon Trickster*, a popular game that requires the child to replicate a sequence of tones and lights. Since then, many technical applications are now available that greatly resemble these tangible games. Instead of using *Blink* (Staupe 2001), a very similar application could be used: *Tip Tap* from *Joe Longstreet* (2011). This app targets working memory, attention as well as processing speed by sorting cards by colour, shape and number as quickly as possible. Instead of *Simon Trickster*, the almost identical application *Simon Says* from *Huge Lawn – Miracle Apps ApS (2013)* could be used and the game *Bop It* is also available in technological format from *Electronic Arts Inc.* (2011). Other types of applications that could improve cognitive skills are hidden pictures games such as *Hidden Pictures* (Games 2010), and *Find the Differences* (Minard 2010) that require children to find differences between two images. Sustained attention is also required for the *Odd Ones Out! Lite* game (Tatiana Churanova 2013), where children need to detect which object does not belong within a scene, and also for the *SymmetryGame – concentration exercise* (Esther Castello solbes 2012), where reproducing the opposite of a given pattern using coloured shapes requires a high level of concentration. Finally, many puzzle games such as *Zentomino* (Little White Bear Studios 2012) can target both attention and reasoning skills, since geometric shapes need to be moved and rotated to complete the puzzle.

Research has demonstrated that computer games can develop complex thinking skills that are associated to problem solving (Keller 1992). Playing video games could foster learning and brain plasticity (Green, Pouget, and Schrater 2012). The use of technology has also been shown to be more motivating for learning than more traditional methods of teaching (Kulik 1994; McFarlane, Sparrowhawk, and Heald 2002). Some specific features associated with these games could be responsible for the increased motivation to learn (Rosas et al. 2003). Examples are their challenging nature, and the fact that they give the player a certain level of control (Jenkins 2002; Lepper and Malone 1987). According to McFarlane, Sparrowhawk, and Heald (2002), the increase in motivation to play technology-based games is directly related to the level of attention and concentration required for these games. Of course, not all games produce favourable results (Rosas et al. 2003).

Some of the effective features of technology-based games for motivation include having a clear goal, an adequate level of complexity (not too hard, but not easily mastered), quick moving stimuli, integrated instructions that children don't need to read, the absence of physical laws on what can fly or change shape, and its inherent holding power (Malone 1981; Provenzo 1991; Rosas et al. 2003; Turkle 1984). While playing these games, children are subject to the *immersion effect*, which is the learning process that happens when a child is submerged into an environment that progressively increases the level of attention and concentration (Hubbard 1991; Rosas et al. 2003). "*Higher motivation, attention and concentration are related to the perception that an activity is ''fun''; that is, visually and cognitively attractive to children* (Rosas et al. 2003 p.76)".

Finally, the use of technology that resembles computer games is more interesting (Papert 1980; Provenzo 1992) and more meaningful (Ausubel, Novak, and Hanesian 1983) for children. Moreover, since a child would be able to play cognitively based applications on an iPad (Apple 2013) or other tablet independently without needing adult participation, it could be a much more feasible way for speech-language pathologists to offer extra treatment hours. Of course, we must mention that parental support is an important part of treatment since they can encourage the use of the proposed applications. Furthermore, parental involvement could also ensure that the child makes more gains in a shorter period of time.

Proposed Treatment Model and Experimental Design

The relationship between cognitive and linguistic skills is of growing interest to researchers studying PLI, particularly to those wanting to improve the language skills of bilingual children. Since the use of technology for learning has grown in recent years and since children are motivated by its use, we suggest a treatment model which incorporates a cognitive non-linguistic approach with the use of new technology and apps that are similar to game counterparts that have been shown to be successful. However, more research is needed to show the effectiveness of this treatment model. Studies comparing a traditional linguistic model to a cognitive non-linguistic model using technology could reveal if this new technique would bring similar or better results. The proposed model could be used as an experimental design for future studies.

It is possible that the ultimate intervention delivery model for children who have PLI encompasses both linguistic and non-linguistic cognitive techniques. If such is true, the games or applications that improve cognitive function could be used between direct linguistic intervention sessions, for example, as homework. Since these games can be played without the help of an adult, they could be ideal as an evening or weekend activity at home. Within such a model, the speech-language pathologist would continue to directly intervene with a child within a traditional linguistic approach. For example, a child could receive one hour a week of direct linguistic intervention for 8 weeks, but also play non-linguistic cognitive games for an hour on days when no direct treatment is received. This would equal to 48 additional hours of indirect intervention to the 8 hours of direct intervention, for a total intervention time of 56 hours. Since robust treatment is a key component to improving language skills (Kohnert 2010), these extra hours could be vital to a successful intervention. In sum, within the model proposed, children would receive traditional linguistic intervention from their therapist and would play tailored non-linguistic cognitive games relevant to the child’s needs as an addition to the treatment plan. Figure 1 illustrates the proposed model, which incorporates more hours of non-linguistic cognitive therapy than hours of traditional linguistic treatment.

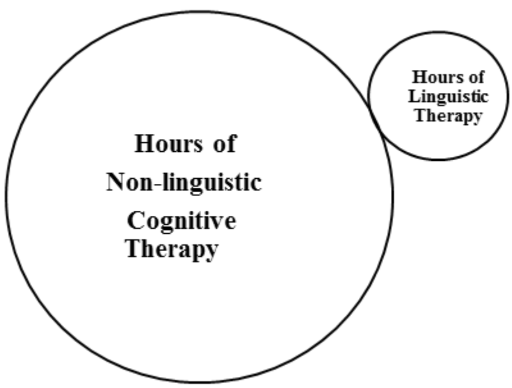

Figure 1: Proposed Model of Treatment

The combination of both approaches would equal more intervention hours, both direct and indirect, which could in turn facilitate language learning at a faster rate. Figure 2 illustrates how the model would apply to monolingual children. In this model, we see how both the linguistic and the non-linguistic approaches complement each other.

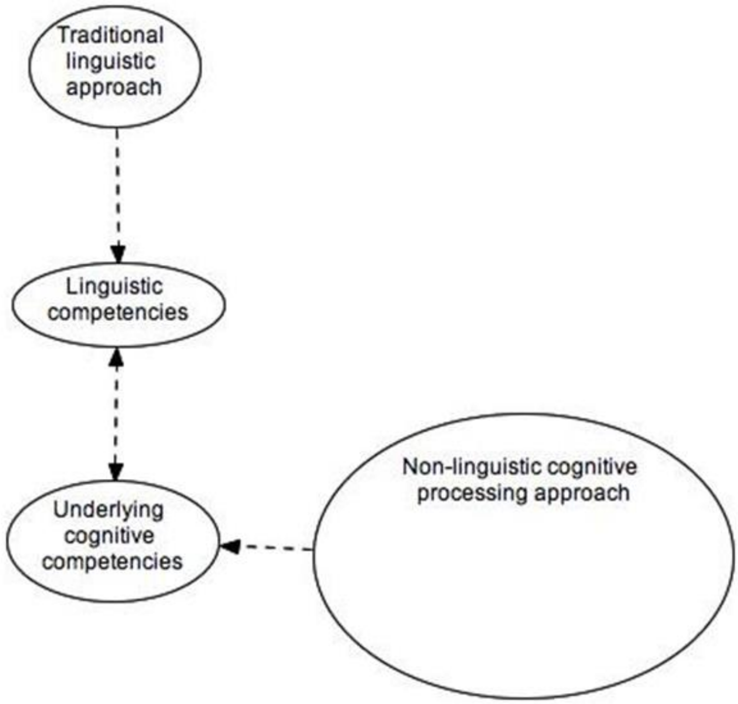

Figure 2: Monolingual Linguistic and Cognitive Intervention

For bilingual children, gains could be made in the child's first language (L1) as well as the second language (L2) even though only one is often targeted during direct linguistic intervention. More specifically, most speech-language pathologists speak the child's L2 (the majority language of the community) but don't speak the child's L1. Figure 3 demonstrates the application of the model with bilingual children while working on the child's L1 and L2, while figure 4 reveals how the model could apply when intervention in the child's L1 is not possible.

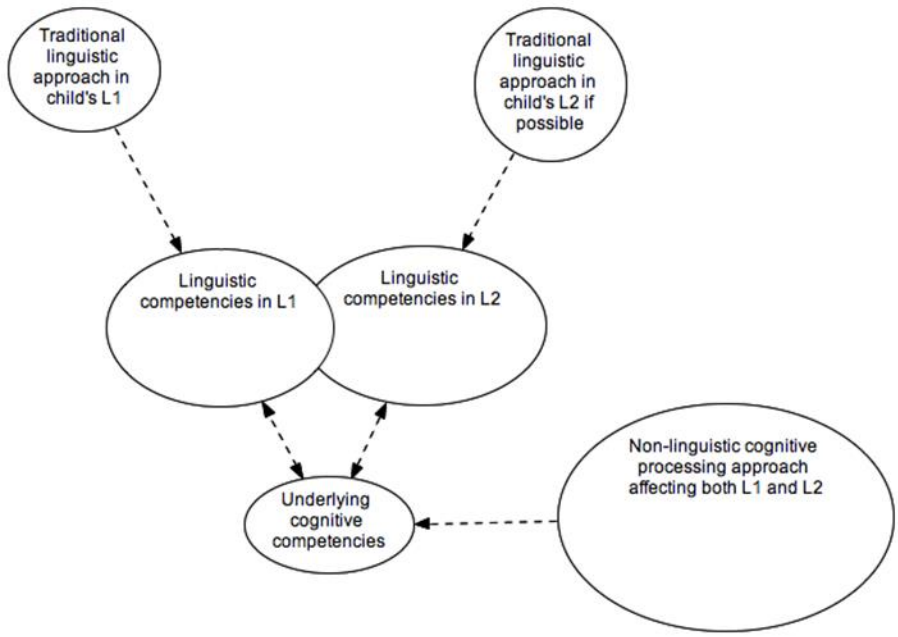

Figure 3: Bilingual Linguistic and Cognitive Intervention

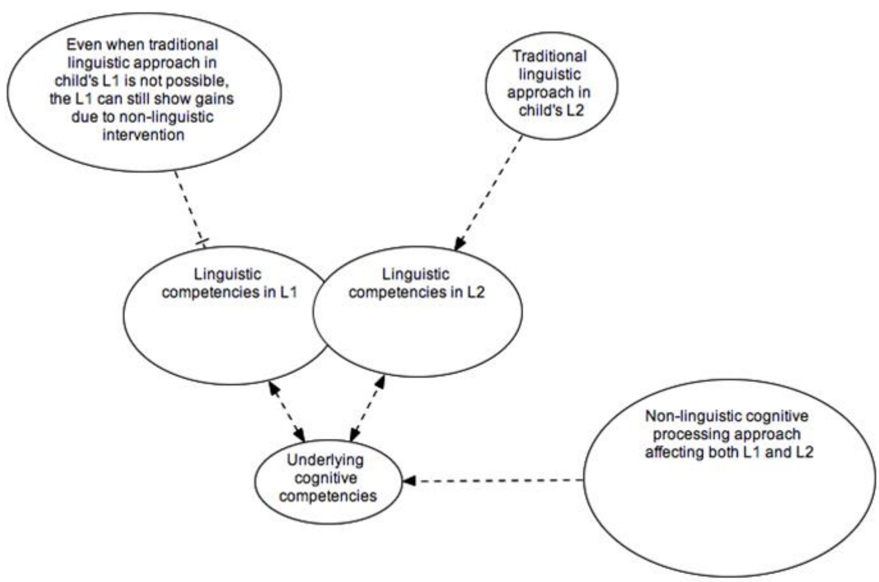

Figure 4: Monolingual Linguistic Intervention with "Bilingual" Cognitive Intervention

To exemplify how this would translate into a regular workweek, table 1 demonstrates a comparison between the traditional model and the proposed model within an 8-week block of intervention. Certainly, the model could be modified to support different lengths of treatment blocks. Poor compliance in the absence of a therapist could play a role in the success of this model.

Although future studies are needed to verify this experimental design, it is hypothesized that the proposed model would be beneficial for children who have PLI.

Table 1: Comparison Between Traditional Model and Proposed Model of Treatment

Traditional Model: LingI = 1 hour of Linguistic Intervention; Total of 8 hours of treatment

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1				LingI			
Week 2				LingI			
Week 3				LingI			
Week 4				LingI			
Week 5				LingI			
Week 6				LingI			
Week 7				LingI			
Week 8				LingI			

Proposed Model: NLCI = 1 hour of Non-Linguistic Cognitive Intervention; Total of 56 hours of treatment

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 2	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 3	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 4	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 5	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 6	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 7	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI
Week 8	NLCI	NLCI	NLCI	LingI	NLCI	NLCI	NLCI

Conclusion

Since language is an integral part of cognition, new research has been able to demonstrate the effectiveness of a cognitive non-linguistic approach for the treatment of PLI using games that target working memory, sustained attention and processing speed (e.g. Ebert and Kohnert 2009; Ebert, Rentmeester-Disher, and Kohnert 2012). The purpose of this article was to propose a new model of treatment encompassing the use of technology for the treatment of PLI. Since adopting a non-linguistic cognitive approach can be a favorable way of increasing language skills for monolingual as well as bilingual children (Ebert, Rentmeester-Disher, and Kohnert 2012), and since the use of new technology can be motivating for children (Kulik 1994; McFarlane, Sparrowhawk, and Heald 2002), the proposed model of treatment pairs technology with a cognitive non-linguistic approach. This dual approach can only be a winning combination for children who have PLI, their parents, educators as well as speech-language pathologists. Since new apps resembling tangible games proven to positively impact linguistic skills are readily available, we can imagine that these new virtual formats could bring similar favorable results, and possibly at a faster rate given the motivational aspect associated with the use of technology. This model proposes the addition of indirect hours of cognitive play on days when linguistic intervention is not received. This could in turn add up to as much as 56 hours of indirect intervention time compared to the traditional 8 hours offered during an 8-week block. The addition of non-linguistic cognitive treatment with the use of motivating technology to the traditional methods of treatment could be cost saving and help children obtain proficient language skills at an earlier age, consequently leading to an innovative approach to the treatment of PLI. Last but not least are the positive outcomes in terms of language development, which could result in improved reading, writing and ultimately better scholarly achievements. Conclusively, the use of technology in the treatment of PLI is a promising tool.

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