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Can Working Memory Be Trained through Learning an Additional Language? the effects of TPR versus PPP

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Abstract

Given the seemingly important link between children's working memory (WM) and their scholastic performance, it would be a worthwhile research enquiry to explore language learning as one potential way to improve WM. To this end, the present study examined the impact of two language teaching paradigms, namely, Presentation-Practice-Production (PPP) and Total Physical Response (TPR), on children's WM over time. Seventy participants, aged 8 to 9 years, were administered tests of phonological, visuo-spatial sketchpad and central executive components, and made up TPR, PPP and control groups for a period of three months. Then, a posttest and a delayed posttest were administered to identify whether the treatments led to significant improvements. The results of the 3 WM measures indicated that the 2 interventions led to certain improvements. Whereas TPR led to significant improvements in the central executive, PPP produced significantly higher gains in phonological memory over time. Neither treatment induced any positive impact on the visuospatial sketchpad. The results lend evidence to the trainability of WM. It is also suggested that language learning experiences have long-lasting repercussions and that each language learning experience can impact certain components of WM.

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Introduction

One important cognitive factor which influences children's scholastic attainment is working memory (WM; Allen & Waterman, 2015; Staff et al., 2018). It deals with the cognitive processes of temporary storing and manipulating information and is supposed to facilitate the functions of complex tasks (Baddeley, 2003). These cognitive processes, which compete to reach the limited resources, are different in capacity from person to person, hence learners' variability in WM capacity. This variability would be reflected in such classroom activities as remembering instructions, writing, performing mental arithmetic, etc. It has been reported that children with a poor WM capacity tend to fail on many of these learning activities (e.g., Gathercole et al., 2006). Thus, considering the apparently close link between WM and children's school performance, it would be relevant to explore the ways that would possibly lead to improvement in WM. This kind of research would have the potential to help low WM children to cope with learning tasks (Gathercole & Alloway, 2004; Holmes et al., 2009; St Clair-Thompson & Holmes, 2008). However, there is controversy as to whether WM can be trained, with some studies suggesting its trainability (e.g., Borella et al., 2017; Gathercole et al., 2019; Klingberg, 2010; Ramani et al., 2019; Rowe et al., 2019; von Bastian & Oberauer, 2013), and some others treating it as a fixed trait like other individual difference characteristics such as motivation, intelligence, etc. (e.g., Miyake & Freidman, 1998; Shipstead et al., 2012).

Furthermore, whether the process of learning an additional language could improve WM is a bone of contention. On the one hand, multilingual learners are likely to face cognitive constraints in some specific language learning situations since they have similar limitations in attention and memory capacity while at the same time they have to attend to more languages (de Bot, 2012; Festman, 2020). On the other hand, multilingual individuals may enjoy an advantage in that they have more resources and have learned to attend to more linguistic systems, hence a larger linguistic repertoire, enabling them to outperform monolinguals in certain WM tasks (see Grundy & Timmer, 2017, for an overview). Therefore, the issue of whether the experience of language learning could improve WM capacity in addition to the learner's language proficiency is far from clear. Nor is it clear whether this potential effect might be different depending on the nature of the language learning experience. In other words, even if language learning has the potential to induce some change in WM, the question that arises is whether different language learning experiences modify WM in different ways. Therefore, this study aims at investigating the impact of two such experiences of learning an additional language. To that end, the effects of two common teaching methods, Presentation-Practice-Production (PPP) versus Total Physical Response (TPR), on different components of WM were explored.

Working memory

There are several WM models (e.g., for a review, see Rowe et al., 2019). However, the most widely used model of WM is the one by Baddeley and Hitch (1974). It was initially comprised of three separate components or subsystems considered to be functioning collaboratively: Two domain-specific systems, which are the phonological loop and the visual-spatial sketchpad, and one domain-general central executive of limited nature. The phonological loop is in charge of retaining auditory information, while the visou-spatial sketchpad deals with information of visual and spatial kinds. The central executive monitors the interplay of these subsystems with other cognitive systems and handles the filtering of information. Later, a fourth dimension, namely, the episodic buffer, was incorporated into the model (Baddeley, 2000). This new subsystem is assumed to be responsible for storing information, and serves the function of binding information, coming from a range of sources, into episodes and integrating information from different modalities to yield a single experience of a multi-faceted nature.

The phonological component is, in turn, made up of two components: a storage system of a temporary nature and a rehearsal system involving subvocalization. The storage component maintains memory traces for very brief periods, with the rehearsal component coming into play to prevent the loss of information by maintaining, registering, and storing them. It has been argued that phonological component plays an important role in some parts of both first language (e.g., Baddeley et al., 1998) and second language acquisition (e.g., French & O'Brien, 2008). It is typically assessed by two measures of digit span (DS) and non-word span (NWS) tasks (Baddeley, 2003; Pickering & Gathercole, 2001).

According to Baddeley (2003), the central executive supervises attentional processes, which can, in turn, be divided into executive subprocesses. As with phonological capacity, the central executive has capacity limitations but it varies from person to person. It has, therefore, been suggested that executive processes can partly justify differences in WM span (Daneman & Carpenter, 1980). The central executive is assessed by some complex WM tasks, namely listening span (LS) and reading span (RS) tasks. Finally, the visuospatial sketchpad is typically assessed by the use of the block recall test (Pickering & Gathercole, 2001).

Language learning and trainability of WM

It is worth investigating the ways to alleviate the difficulties resulting from poor. One way involves the more manageable presentation of the material in the classroom (Yang et al., 2015). This includes simplifying task instructions and sentences, and also shortening them, and providing some memory aids to enhance the input (Gathercole & Alloway, 2004, 2008).

Although the above method could go toward reducing the heavy workload that low WM students are faced with (St Clair-Thompson et al., 2010), it is impossible to ensure that teachers everywhere would follow through. Therefore, another approach is required that would aim to train WM in low WM students. However, a bone of contention among WM researchers concerns the idea of whether WM is a trainable construct (Klingberg, 2010; Klingberg, et al., 2002) or a fixed trait like other individual difference characteristics such as motivation, intelligence, etc. (Miyake & Freidman, 1998; Shipstead et al., 2012). A number of studies have addressed this issue, indicating that it is possible to improve WM (e.g., Gathercole et al., 2019; von Bastian & Oberauer, 2013). An early attempt to investigate this issue was made by Klingberg et al. (2002), leading to improve task performance significantly. The participants of the study were children diagnosed with attention-deficit hyperactivity disorder (ADHD) who were assessed by some WM tests or tasks. Similarly, Holmes et al. (2009) also reported improvements in children selected based on poor WM performance. The study investigated the effects of an intervention program on the children's mathematical reasoning scores and found significant gains. However, there are also studies in the literature which did not identify any intervention effects for WM failures (for a review, see Vollebregt et al., 2014).

A number of intervention approaches have been identified and introduced as a result of effective interventions on WM. These include changing and modifying the environment to minimize the amount of WM load, training skills and strategies which contribute to WM indirectly, and training WM directly via the use of certain strategies (Rowe et al., 2019). Considering such interventions' effective potential to improve WM has raised the question of which children can benefit much more from such interventions and to what extent they need them (Justice, 2018). For example, it has been pointed out that there is still much uncertainty as to the optimum amount of intervention in the domain of child development (Justice, 2018).

With respect to the role of language learning experiences on WM, matters seem a bit more complicated. One hypothesis is that bilingualism incurs certain costs related to cognitive constraints since bilinguals have similar limited attention and memory capacity sources while they have more language resources in hand (de Bot, 2012). Alternatively, multilingual learners could be argued to enjoy an advantage in that they have more resources to draw on. In this regard, Morales et al. (2013) found that in WM tasks, especially in executive functioning ones, bilingual children outperformed monolinguals. Similar effects have also been reported for experienced simultaneous interpreters, as compared to novice interpreters and non-interpreters (Hervais-Adelman & Babcock, 2020). The results of a meta-analysis also confirmed the idea of bilinguals' WM advantage over their monolingual counterparts (Grundy & Timmer, 2017).

However, there is still a call for empirical studies that would explore the effects learning an additional language could have on WM. To this end, recently, Huang et al. (2020) explored the cognitive advantages of learning several languages on language aptitude (LA) and WM in adults. Specifically, they investigated whether LA and WM change as a result of learning foreign languages and also the number of languages learned (i.e., one, two, or three languages at the same time) would modulates the impact. The findings showed that all participants' LA and WM have been improved. Furthermore, the intensity of the language learning experience had a significant effect on WM improvement, with first-year learners with two foreign languages outperforming their one-foreign-language counterparts in WM improvement.

Similarly, Hayashi (2019) explored the impacts of a computerized WM training software on the participants' WM and language proficiency but identified no significant effects. However, the study did identify correlations between general oral proficiency scores and improvements in a verbal WM task. A shortcoming of these studies is that they did not delve into the nature of the instruction the different groups received, nor did they indicate which subsystems of WM was impacted by the language learning experience and to what extent. To address these research lacunas, in the current study, two language teaching interventions, namely PPP and TPR, were explored, to examine whether they can exert any effect on the three main components of WM.

Presentation-Practice-Production (PPP) and Total Physical Response (TPR)

PPP is a language teaching paradigm for designing language lessons, made up three stages of *presentation, practice, and production*. In the presentation stage, the teacher first introduces a new language item by drawing learners' attention to the pronunciation, spelling, form, and meaning of it. In the practice stage, learners are required to speak or write the target form by using some controlled exercises. In the third phase, learners have opportunities to produce the target language items via speech or writing (Ur, 2018).

TPR refers to a method of language teaching through which speaking and acting work in tandem (Richards & Rodgers, 2014). Developed by James Asher (1977), it uses several traditions such as humanistic psychology, developmental psychology, learning theory, and several language-teaching proposals. Asher (1977) notes that most of the grammatical structures and vocabularies can be taught to learners by using imperatives. Furthermore, he has provided an account of the factors that could contribute to or inhibit language learning by drawing on three rather influential learning hypotheses, namely, the existence of an innate bio-program, brain lateralization, and the affective filter. Therefore, a typical TPR class would be filled with action-based imperative drills, with initial attention to meaning, with the learner taking on the role of a listener and a performer.

The reason why TPR and PPP have been chosen concerns the findings in the literature (e.g., Gathercole et al., 2006; Takeuchi et al., 2020; Yang et al., 2015). Gathercole et al. (2008) suggested that performing action sequences would tap the phonological loop and central executive more than immediate oral repetition in children. The observation has been reflected in a number of studies (e.g., Jaroslawska et al., 2016; Waterman et al., 2017; Yang et al., 2015). Furthermore, it has been suggested that managing to follow instructions successfully in educational settings is related to the students' ability to encode and act on instructions they hear or read (Gathercole, et al. 2006; Gathercole, et al., 2008; Yang, et al., 2015), which is characteristic of TPR. The method, therefore, appears to be a potentially suitable teaching method for testing the impact of language instruction on WM. On the other hand, it has been investigated that read aloud, repetitions, and shadowing in a second language, which are typically found in PPP, have positive effects on WM capacity, specifically on phonological memory (Takeuchi et al., 2020). PPP has also been praised as being effective for low-level learners with disadvantaged backgrounds in a particular subject (Muijs & Reynolds, 2011) and in non-English speaking countries, particularly in contexts where the course is only held for three or four sessions per week (Ur, 2018).

Purpose of the study and research questions

Given that both PPP and TPR can readily be incorporated into schools, they can be viable methods of improving WM. Also, since research, to date, has been mainly conducted on children with ADHD (e.g., Klingberg et al., 2002) or those suffering from poor WM (Holmes et al., 2009), a second objective is to examine the effect of PPP and TPR in a sample of normal children and to explore whether these two types of intervention will lead to different effects on WM and which components of WM will be affected by these two types of intervention. Thus, the following research questions were formulated:

1. Does the experience of learning a foreign language learning lead to any improvements on WM?

2. Is there any difference between PPP and TPR in terms of the changes, if any, they bring to components of WM?

Method

The study used a quasi-experimental pretest-posttest design. A delayed posttest was also administered to the participants to shed light on the long-term effects of the interventions, if any. To ensure that the results obtained were by the treatment only and the three groups were comparable before the study, a pretest was administered before the treatment. As for sampling, two intact classes were assigned into each of the experimental groups, and one class into a control group. One class from one language center was selected as the TPR group and one class from another language center was chosen as the PPP group. The selection of the participants from two different language schools was done to ensure that the two types of treatment options would be adhered to as scrupulously as possible, since one of the language schools used TPR and the other, PPP. A second reason was to ensure that the centers' instructional approaches would not be disrupted, in line with the ethics of research and to obviate the need to make changes to any centers' preferred methodologies.

Participants

Seventy participants aged eight to nine years from two private language centers, one practicing TPR (*n* = 25) and the other, PPP (*n* = 24), and a state school (*n* = 21), from Shahrekord, Iran, were chosen. The participants were native speakers of Persian. The control group was chosen from a state school which did not offer any second language courses to students of this age. It was ensured via a questionnaire filled by their parents. Consent forms were also submitted to the participants' parents and the school administrators.

Instruments

Linguistic Profile Questionnaire

The Language and Social Background Questionnaire, constructed by Anderson and his colleagues (2018), was used to provide background information about the participants such as education level, age, L1, L2, L3, frequency of usage of the languages, gender, context and age of learning each language, ethnic group, and length of stay in Iran. It was piloted on 20 individuals. Also, the internal consistency and test-retest reliability of the instrument was obtained.

Memory Measures

Three standardized Persian tests of digit span, block recall, and listening recall test (Arjmandnia et al., 2020) were administered to the participants to measure their phonological, visuo-spatial, and central executive components, respectively, modelled after the measures in Memory Test Battery for Children (WMTB-C, Pickering & Gathercole, 2001). All the participants were administered the three measures three times, one before the interventions, and one test immediately after the interventions, and one four weeks later.

In the digit recall task, according to Pickering and Gathercole (2001), some digits were presented to the participants, one digit per second. The task started with a sequence of three digits. The number of digits increased gradually until the participants failed to say the exact sequence. The scores of the participants were calculated as the number of digits which they could recall and repeat correctly.

In the block recall test, participants recalled the sequence of the numbers shown on a series of blocks. The number of blocks gradually increased as the participants recalled the correct sequence. The scores of the participants were the number of the correctly recalled sequence (Pickering & Gathercole, 2001).

As for the listening recall test, which is a measure of the central executive component, participants listened to some sentences and thought about the veracity of each sentence. Moreover, they recalled and said the last word of each statement in a set. The scores of the participants, as with the two previous tests, were the number of the final sequence which the participants could recall and say correctly (Pickering & Gathercole, 2001).

Test of intelligence

Raven's Progressive Matrices (RPM; Raven et al., 1998) was administered to measure nonverbal intelligence to ensure that performance on the WM measures would more likely be associated with the second language learning experience than intelligence.

Procedure

Tests of phonological component, visuo-spatial sketchpad and central executive were administered to children aged eight to nine years old. The children were then exposed to one of the three conditions, namely, TPR, PPP, and control for a period of three months. Then, a posttest and a delayed posttest were administered to indicate whether the treatments led to significant improvements, compared to the control group.

The children in the intervention groups received English exposure and instruction through PPP and TPR over a period of three months, completing three sessions of an hour each week. The language centers were chosen based on the instructional approach they were using, with one center using TPR and the other using PPP, and one that did not offer any second language courses to students of this age.

As stipulated in the curriculum of language centers practicing TPR, the TPR group were engaged in action-based imperative drills, with initial attention to meaning, with the learner taking on the role of listener and performer. A sentence-based syllabus, revolving around grammar and lexis was used. In line with TPR principles, as described by Asher (1977), the teachers used commands, with the verb being the linguistic motif of the commands, and had the students perform the commands. Physical activities on the part of the learners after the initiation of the teacher's command were incorporated into the class to ensure that the right hemisphere would be engaged in the class activities (Asher, 1977). To provide a stress-free environment for the learners, activate the innate bioprogram of the learners (Asher, 1977) and ensure a low-affective factor on their part, the students were not required to produce any language until they felt ready to do so.

In the PPP group, on the other hand, a new language item was initially introduced by the teacher who drew attention to the spelling, form(s), meaning, and pronunciation of the item. Then, the learners were engaged in the target form by doing controlled exercises including sentence-completion or multiple-choice types. Finally, the learners were allowed to engage in free production of the target items in oral or written modalities. All the participants in the experimental groups were taught Magic Times Book series, second edition (Kampa & Vilina, 2012).

Results

Statistical analysis identified no significant differences among the groups at the outset of the study (*p* > .05 in all cases). To address the research questions, three repeated measures ANOVAs were used to examine the gains, if any, from pre-test to posttest and delayed posttest on the three WM measures.

WM Measures

The descriptive statistics for the digit recall task (i.e., group means and standard deviations) for the groups over time is shown in Table 1 and the means are also displayed on the graph in Figure 1.

Table 1 Group means and standard deviations for the digit span task

	Pretest		Posttest 1		Posttest 2	
	M	SD	M	SD	M	SD
PPP	26.79	2.22	33.58	2.81	32.29	2.66
TPR	26.84	2.56	26.96	2.16	27.28	3.79
Control	26.80	4.50	29.24	4.24	27.04	4.47

These results demonstrated that the PPP group did better than the other two groups on posttests 1 and 2. Significant effects were confirmed for group, F (2, 67) = 11.59, $p < .05$, $\eta_p^2 = .25$ and for time F (2, 66) = 191.11, $p < .05$, $\eta_p^2 = .85$, as well as a significant Time × Group interaction, F (4, 132) = 75.75, $\eta_p^2 = .069$. Tukey's post hoc pairwise comparisons were employed to determine the source of the significance, with a set alpha level of .05 for all subsequent post hoc analyses. First, it was revealed that there was no significant difference among the three groups on the pretest. Second, the PPP group significantly outperformed the other two groups at posttest 1, when the TPR group did not significantly outperform the control group. While the PPP group did significantly better than the other two groups on posttest 2, there was no significant difference between the TPR group and the control group.

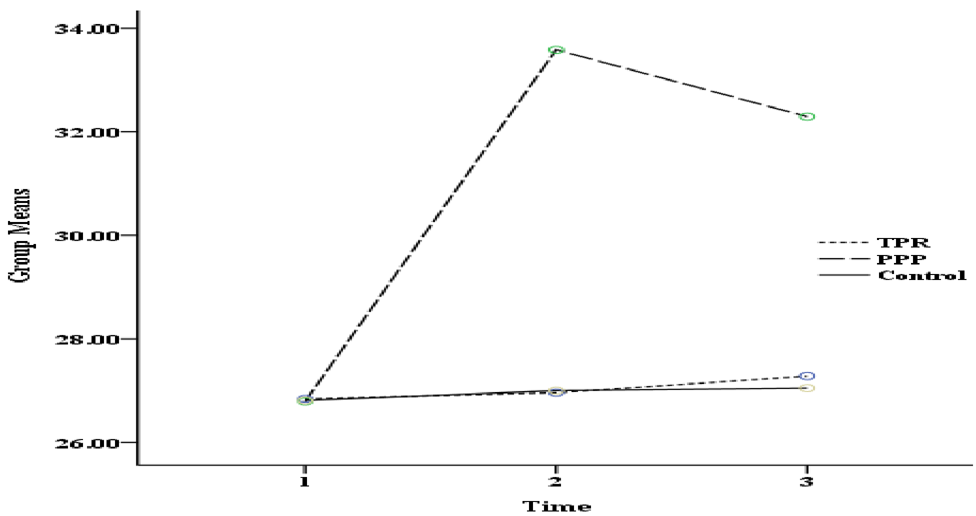

Figure 1. Group means on the digit span task over time.

Descriptive statistics for the block recall task are shown in Table 2, and the means are displayed in Figure 2.

Table 2 Group means and standard deviations for the block recall test

	Pretest		Posttest 1		Posttest 2	
	M	SD	M	SD	M	SD
PPP	23.29	2.13	23.25	1.91	23.16	1.76
TPR	23.12	2.53	23.32	2.26	23.52	2.31
Control	23.23	2.36	23.23	2.21	23.04	2.53

The results show that the groups did not identify any significant differences for group, F (2, 67) = .02, p = .97, η_p^2 = .001, for time F (2, 66) = .164, p = .84, η_p^2 = .005. Nor was a significant effect detected for Time × Group interaction, F (4, 132) = 1.47, p = .21, η_p^2 = .043.

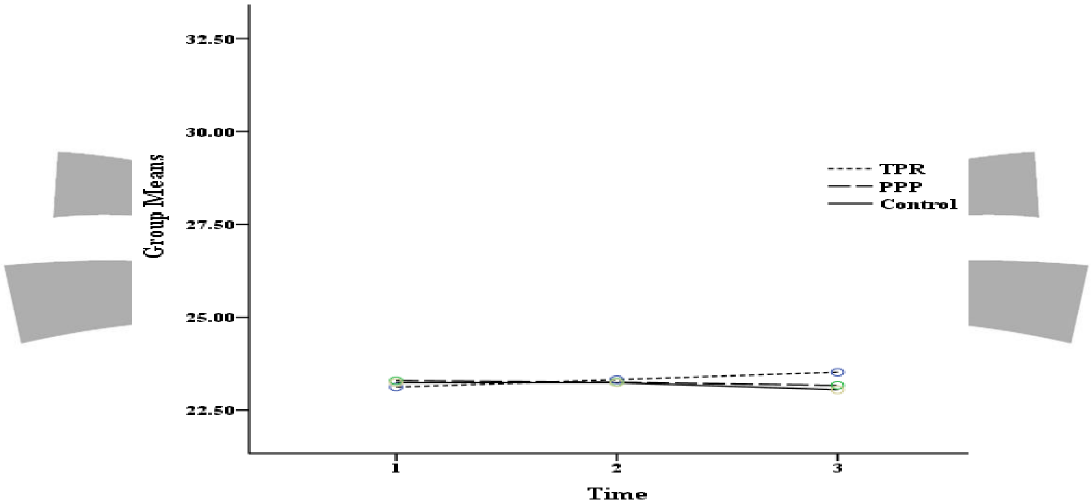

Figure 2. Group means on the block recall test over time.

Table 3 shows the descriptive statistics for each group, and Figure 3 presents the group means. Unlike the results of the digit recall test, the statistics show that the TPR group significantly performed better than the other two groups on the immediate and delayed posttests. Significant differences were detected for group, F (2, 67) = 24.86, p < .05, η_p^2 = .426, and for time, F (2, 66) = 241.23, p < .05, η_p^2 = .88, as well as a significant Time × Group interaction, F (4, 132) = 82.43, p < .05, η_p^2 = .71. Tukey's post hoc pairwise comparisons showed that there were no significant differences among the three groups on pretest, and that the TPR group did better than the other two groups on both posttests 1 and 2. No significant differences were detected between the PPP group and the control condition on the immediate and delayed posttests.

Table 3 Group means and standard deviations for the listening recall test

	Pretest		Posttest 1		Posttest 2	
	M	SD	M	SD	M	SD
PPP	14.5	2.32	14.58	1.99	14.75	2.19
TPR	14.12	2.47	21/04	2.80	20.16	2.74
Control	14.09	2.09	14.61	1.80	14.66	1.71

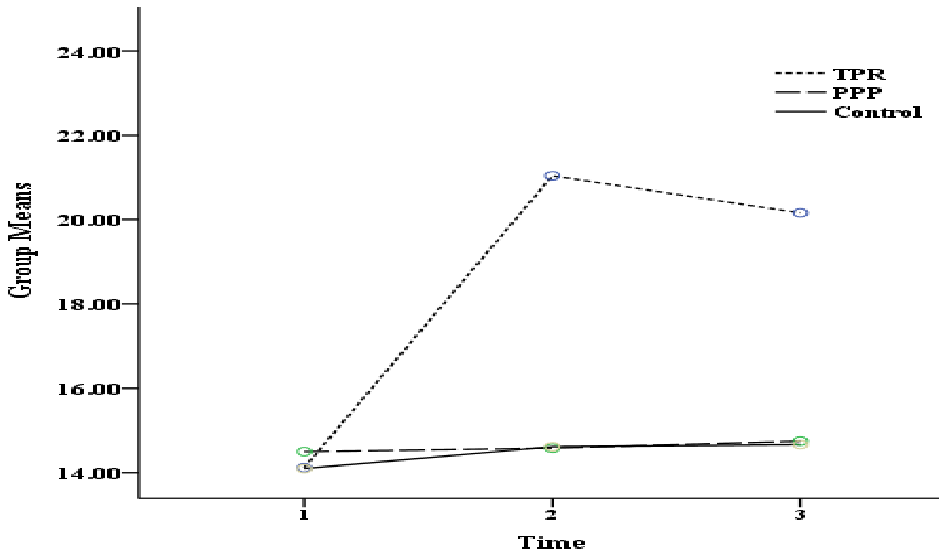

Figure 3. Group means on the listening recall test over time.

Discussion

The present study aimed to investigate the impacts of PPP and TPR on children's WM over time. The results of the analyses of variance on the three WM measures indicated that the two interventions did lead to certain improvements. More specifically, while TPR led to significant improvements in the central executive, PPP produced significantly higher gains in phonological memory over time. It was also found that neither treatment induced any positive change in the visuospatial sketchpad. It is noteworthy that the same patterns recurred on the delayed posttest, indicating that language learning experiences seem to have long-lasting repercussions. The findings are consistent with the finding that memory improvements can result from strategy-based training as opposed to direct practice on memory tasks (St Clair-Thompson & Holmes, 2008).

The results confirm the idea that WM, as one such cognitive function, in particular, could be trained (e.g., Borella et al., 2017; Gathercole et al., 2019; Klingberg, 2010; Ramani et al., 2019; Rowe et al., 2019; von Bastian & Oberauer, 2013) and is not to be treated as a fixed trait. The findings also side well with the argument that language learning confers the advantage of possessing a larger linguistic repertoire, enabling bilinguals to outperform monolinguals in certain WM tasks (Grundy & Timmer, 2017, for an overview). As noted in the literature review section, similar effects have been recorded for experienced simultaneous interpreters (Grundy & Timmer, 2017; Hervais-Adelman & Babcock, 2020). Consistent with Huang et al. (2020), reporting a positive impact for the intensity of the language learning experience on WM, the results hint at the idea that the nature of the language learning experience could also produce a similar outcome. However, the results are inconsistent with some other studies in the literature, which could be attributed to methodological differences (Hayashi, 2019). Thus, it can be argued that overall, the additional language does not seem to present cognitive constraints in memory capacity and attention.

Regarding the second research question, it was found that PPP was more conducive to gains on the phonological component of WM, whereas TPR led to significantly higher gains on the central executive. However, neither treatment impacted the visouspatial sketchpad. This is consistent with Gathercole et al. (2008), reporting performance, generally, to be more than twice as accurate in the action as in repetition conditions for different measures. The reason why TPR seems to tap the central executive is possibly because it allows a silent period in the beginning, thereby providing more room for both processing and storage to take place. The method, thus, seems to pave the way for the development of a cognitive map fitting the second language, in line with its innate bioprogram hypothesis. The improvement in the central executive could also have to do with performing motor movements, which, in turn, involve right-brain learning. This is consistent with Gathercole et al.'s (2008) speculation that certain conditions provide grounds for the formation of a motoric or spatial representation. In the same vein, they argue that performing verbal instructions would require additional demands on WM above and beyond immediate recall. Finally, the impact could also be linked to the concept of a relatively stress-free environment, given its considerable emphasis on meaning. This superior performance of TPR group on the listening recall test could also be attributable to the notion of transfer-appropriate processing (TAP; Révész, 2012). TAP postulates that learning is very much hinged on the extent to which the learning and retrieval conditions are similar. It could, therefore, be argued that the TPR conditions were more in line with the listening recall test.

The emphasis on incorporating physical engagement into curricular activities to compensate for WM has also a recurrent theme among a number of previous studies (e.g., Jaroslawska et al., 2016; Waterman et al., 2017, Yang et al., 2015). Overall, these studies emphasize the development of techniques and methods that assess and support instructions appropriate for different populations, age groups, and contexts. Consistent with such studies, the present study also suggests that physically engaging the students in tasks could not only compensate for but also boost the central executive. It should be noted, however, that these studies have typically used tasks related to following classroom instructions as their dependent variables. By contrast, in the present study, we used WM components as the dependent variable. It would, therefore, be relevant to investigate in future studies if the gains reported for WM components could be transpired on classroom tasks as well.

The reason why the PPP group had significantly higher gains in phonological memory has possibly to do with the idea that it seems to provide opportunities mostly for increasing the storage capacity involved in phonological short term memory. It seems, therefore, that WM scores can reflect how far the different components of WM are tapped. Therefore, it would be relevant, in assessing the performance of different WM components, to look into the backgrounds of the participants (e.g., Barrouillet et al., 2004).

On the other hand, it has been investigated that read aloud, repetitions, and shadowing in a second language, which are typically found in PPP, have positive effects on WM capacity, specifically on phonological memory (Takeuchi et al., 2020). PPP has also been praised as being especially beneficial for students from low social classes, or students with a poor level of achievement in a certain field (Muijs & Reynolds, 2011), or in non-English speaking countries, particularly in contexts where time is limited to a formal course of three or four hours a week (Ur, 2018). However, according to the results of this study, an overreliance on PPP in such contexts could boost the learners' phonological memory at the expense of neglecting the central executive memory.

One important point to consider is that neither of the two interventions resulted in significant gains on the block recall task. This may be attributable to the domains-specificity of the treatments. Whereas PPP focus on the strategies of rehearsal, TPR engages students in rehearsal and actions. Therefore, it is possible that the students may not manage to generalize from domain to domain (Ericsson & Chase, 1982), so the methods may not provide conditions that would lead to improvements on the block recall task. For instance, block recall involves spatial chunking (e.g., Ridgeway, 2006), which is absent in either of the treatments.

The results show that PPP and TPR could be used as productive tools to provide a means of improving different components of WM in classroom tasks that demand considerable storage. A question that arises at this juncture concerns the transfer of these advantages to tests of certain abilities (St Clair-Thompson et al., 2010) such as reading or arithmetic ability. Nonetheless, consistent with the recommendations for the use of these methods as effective teaching methods in deprived countries (Ur, 2018), the results show that the application of PPP could be beneficial for learners with a low phonological memory and that the use of TPR could help learners with a low complex WM capacity. The adoption of such methods in low WM children could be an important step in disrupting the pattern of failures experienced by these children and thus influence children's impetus for learning (e.g. Aunola et al., 2002).

Further research is required to look into the effects of these and other instructional methods on other WM tasks. Also, the use of several tasks to measure the phonological loop, visuo-spatial sketchpad and central executive components of WM (e.g., Pickering & Gathercole, 2001) is proposed. Furthermore, there is a call to further explore the idea of whether strategy training could lead to better performance of other tasks. The significance of this study is that the majority of the studies on the link between WM and language learning have focused on the relationship between the two constructs in nature. Future studies could compare and contrast other prevalent language teaching methods to provide a more fine-grained picture of this link.

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