Research Article

Role of Rehearsal Language in Working Memory

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Abstract

The current study investigates the effect of the language of rehearsal on working memory spans. We hypothesised that, in bilinguals, rehearsal in a language whose digits are shorter in length leads to better working memory spans compared to rehearsals in a language with longer digit length. We measured backward digit spans in 24 bilingual individuals with proficiencies in Kannada (native language) and English rated as 'good' or better. The backward digit spans were measured under three conditions; (i) no instructions regarding rehearsal language, (ii) overt rehearsal in Kannada, (iii) overt rehearsal in English. Digits were presented only in Kannada language for all the three rehearsal conditions. Results indicated that rehearsal in English (shorter digit length) resulted in higher scores than the other two conditions. The results provide evidence to the existence of word-length effects even at the level of rehearsal strategies.

INTRODUCTION

Working Memory (WM) refers to the temporary storage and manipulation of sensory information, as required for various cognitive tasks (Baddeley, 2003, 2010). Typically, the WM system works by first directing attention towards the target stimuli. The stimuli that are attended to are temporarily stored in the WM system. However, the WM system is limited in its capacity, and therefore, the 'memory trace' that is generated fades within a few seconds (Baddeley, 2003; Campoy & Baddeley, 2008; Henry, 2012). Individuals, therefore, need to use different 'rehearsal strategies' such as subvocal or overt articulation of the target signals to overcome the effect of decaying memory trace. In this paper, we discuss a specific aspect of rehearsal – the choice of rehearsal language as a strategy – in bilinguals on backward digit (BD) span.

Over the last few decades, many researchers have investigated the role of articulatory rehearsal strategies on the WM spans. Rehearsal strategies are techniques (internal/mental) that an individual employs to facilitate the processing and/or storage (Turley-Ames & Whitfield, 2003) of sensory information. These strategies can include overt or covert (subvocal) vocalisation (Baddeley, Buchanan, & Thomson, 1975; Neath & Nairne, 1995), verbalising and/or visualising (Rayner & Riding, 1997), intonation-based grouping (Glanzer, 1976) etc. Dunn, Gaudia, Lowenherz, and Barnes (1990) reported that listeners use highly individualistic and amorphous rehearsal strategies during BD span task. The interested reader is referred to Dunn et al (1990) for an excellent review of rehearsal strategies used by individuals during digit span tasks. It is suggested that choice of rehearsal strategies may be responsible for the individual variations seen in WM span (Baddeley, 2000b; Bailey, Dunlosky, & Hertzog, 2009; Hilbert, Nakagawa, Puci, Zech, & Buhner, 2015). Simply put, those who employ the most appropriate/optimal strategy for the situation will have the greatest reserve of the 'limited' cognitive resources – greater the available cognitive resources, better the performance on WM tasks (McNamara & Scott, 2001).

Another factor that determines performance of a participant in a WM task pertains to the stimulus characteristics. In WM tasks involving digit or word recall, it is shown that words which require lesser time to articulate are remembered better than words which take longer time to articulate (Baddeley et al., 1975). This aspect of WM is called the 'word-length effect' (Neath & Nairne, 1995). It has been reported that the same numbers/digits can take different times to articulate due to differences in the number of syllables in different languages (Ellis, 1992). For example, the Arabic language has two variations – long and short versions – of digits. This means that, although conceptually identical, each digit can be pronounced in two different ways, both differing in length (number of syllables) but are conceptually identical. Shebani, Van De Vijver, and Poortinga, (2005) reported that BD spans were significantly smaller for the longer version of the digits compared to the shorter version. Similar results are also reported in other languages such as Chinese versus English (Stigler, Lee, & Stevenson, 1986), Mandarin versus English (Mattys, Baddeley, & Trenkic, 2017) and English, Spanish, Hebrew and Arabic (Naveh-Benjamin & Ayres, 1986). These studies show that syllable length and duration of the digits vary across languages and that these differences affect the BD span (Van De Vijver, 2015).

Similar differences in word lengths (or number of syllables) are observed in Indian languages as well. While the digits are mostly monosyllabic in English (except zero and seven – bisyllabic), they are bisyllabic (occasionally trisyllabic) in some South Indian Dravidian languages such as Kannada, Malayalam, Tamil, and Telugu. For example, in the Dravidian language Kannada, digits 'zero', 'one', and 'three' are produced as 'sonne', 'ondu', and 'mooru' respectively which are all bisyllabic. Therefore, the characteristics of the language must be considered while designing and interpreting working memory tasks.

Bilinguals can make effective use of such differences in word/digit lengths. Previous research on bilingual individuals has shown that digit recall spans are better in the language whose digits are shorter in length. Ellis and Hennelly (1980) reported shorter digit span in Welsh language compared to English in Welsh-English bilinguals. They attributed these findings to significantly longer duration of Welsh digits compared to English. Other investigators have also reported similar results in bilinguals of other languages like English-Italian (Brown & Hulme, 1995), English-Chinese (Cheung & Kemper, 1994; Hoosain, 1979), Finnish-Swedish (Chincotta, Hyönä, & Underwood, 1997), etc.

The studies mentioned above showed that the recall language (and its word length characteristics) could influence the digit spans. A corollary of this can also be possible in the 'rehearsal language'. Bilinguals can choose to rehearse the stimuli in either of the languages known to them. It has been suggested that bilinguals have better 'metalinguistic awareness' (Ter Kuile, Veldhuis, Van Veen, & Wicherts, 2011). Metalinguistic awareness refers to an individual's ability to 'think and reflect' upon the different functions of a language, as well as intentionally manipulate the linguistic components (Friesen & Bialystok, 2012). This would mean that bilinguals can consciously choose to rehearse in either of the languages known to them to ensure optimal control of (and respond to) the given linguistic information. That is, during a digit recall task, irrespective of the language of stimulus presentation, bilinguals have the option to decide the most optimal rehearsal language (the language whose digits are shorter in length) to ensure the most optimal response. The choice of rehearsing in either of their two languages is a rehearsal strategy that is unique to bilinguals. It is, therefore, possible that bilinguals can strategically choose to rehearse in the most optimal language.

We hypothesise that, in bilingual participants, rehearsing in the language with the shorter digit length results in better digit spans than in the language with longer digit length, and vice versa. If this is true, then, explicit instruction regarding the rehearsal language is necessary while testing a bilingual participant, as rehearsal language could be a potential variable influencing the BD span scores. Therefore, we measured BD spans in bilingual individuals to stimuli presented in Kannada language, where they were explicitly instructed to engage in overt rehearsal in both their proficient languages. Specifically, we aimed at observing the differences in BD span scores with rehearsal in Kannada versus English, in spite of the digits being presented only in Kannada. Kannada digits are either bisyllabic or trisyllabic (Malda et al., 2008), whereas, English digits are monosyllabic (except seven). This would mean that the Kannada digits take longer to articulate than the English digits. Therefore, we hypothesise that the BD spans would be longer when rehearsed in English compared to Kannada.

METHODS

Participants

We recruited 24 participants (10 males, 14 females), with a mean age of 21.15 years (range = 18 to 25 years). Hearing thresholds of all participants were within 15 dB HL at the octave frequencies between 250 Hz and 8000 Hz. All participants were native speakers of the Kannada language. All participants had a minimum of 12 years of formal education, with the medium of instruction being English. Additionally, all participants signed an informed consent, according to the Bio-behavioral ethics guidelines, prior to the commencement of the experiment.

All participants rated their proficiency in both Kannada and English languages using the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumfield, & Kaushanskaya, 2007). The LEAP-Q is a self-reporting questionnaire designed to quickly obtain proficiency of language usage, particularly in bilinguals (Conrad, Recio, & Jacobs, 2011; Kaushanskaya, Blumenfeld, & Marian, 2019). Multiple previous studies (Anderson, Mak, Keyvani Chahi, & Bialystok, 2018; Prior & Gollan, 2011) have utilised the LEAP-Q to obtain the proficiency of the languages. The procedures for the usage have also been validated and replicated (Kaushanskaya et al., 2019; Marian et al., 2007). The LEAP-Q provides, among other measures, a self-rated proficiency score for both first language (mother tongue/native language) and second language.

Table 1 provides details of the LEAP-Q for all the participants. The 'exposure to language (%)' represents the frequency (in percentage) the participants are exposed to either language. The 'choice of language to read' and 'choice of language to speak' represents the frequency with which the participants chose to read and speak in either language respectively. The 'age of acquisition' refers to the age at which the participants began acquiring the particular language. Since all participants were native speakers of Kannada, all of them began acquiring the language since birth. The 'age of fluency of speaking' and 'age of fluency of speaking' represents the age (in years) at which the participants rated themselves as being fluent with regards to speaking and reading either language respectively. 'Proficiency' refers to the self-rated proficiency in either language, which was obtained by taking the mean of three sections – speaking, understanding, and reading.

All participants were sequential bilinguals with English as the second language. All participants self-rated their proficiency in Kannada with a minimum score of '8' (rated as 'Very Good') for the 'Speaking', 'Understanding of Spoken Language' and 'Reading' sections. They also rated themselves with a minimum score of '7' (rated as 'good') for English proficiency for the same three sections. We also included an additional question into the questionnaire to rate the frequency with which they used English or Kannada language digits in regular conversation. A rating of 1 was given for using 'only Kannada' digits in daily conversation while a rating of 10 was given for using 'only English' digits in conversation. Most participants (20 out of 24) used the digits in both languages equivalently in regular conversation.

Stimuli

All digits for the experiment were presented in the Kannada language. According to the 2011 Census of India, Kannada is spoken by approximately 43 million people, predominantly in the South Indian state of Karnataka, India. It is a verb-final (predominantly subject-object-verb) language with a predominant CVCV syllable structure, with words ending with open syllables (Nag & Snowling, 2011). Kannada mostly has bi- and tri-syllabic words with few words containing up to six syllables. Monosyllabic words are sporadic and can only be observed in some of its dialects (Nag, Treiman, & Snowling, 2010). More details regarding the phonemic and phonotactic characteristics of the Kannada language can be found in Rupela, Manjula, and Velleman (2010).

Eight digits in Kannada language, spoken by a native female speaker, formed the stimuli for the BD span task. Digits between zero and eight, except two, were chosen. All digits chosen were bisyllabic in nature (e.g. 'naaku', 'aidu', 'aaru' for the digits four, five and six respectively). The digit 'two' was not chosen because it was trisyllabic (pronounced 'eradu' in Kannada). The mean duration of the digits was 560 ms.

Procedure

BD spans were measured on all participants. The choice of BD span is based on previous reports that it is more complex than the forward digit span since BD spans require both storage and concurrent mental reordering of the information (Wilde, Strauss, & Tulsky, 2004). Yet, the BD span is simple enough to ensure that there is no flooring effect in any of the participants. All the measurements were conducted in a sound-treated room with acceptable noise levels (ANSI, 2003). The stimuli were presented at 75 dB SPL using a Lenovo-Z50 personal computer connected with Sennheiser HD 380 pro (Wedemark, Germany) headphones. The BD task was carried out using the 'Audio-Backward Span' module of the custom-designed in-house software called Smriti-Shravan (Maruthy & Kumar, 2013). The participants were instructed to listen to a sequence of digits, rehearse verbally, and type-in the sequence in the reverse order. To gain familiarity with the task, all participants were first given a practice trial with sequences of three and four digits. Feedbacks regarding the correctness of the responses were also provided during the practice trials. The practice trial was not included for calculating the span scores. Once familiar with the task, an adaptive one-up-one-down technique, as used in Basavanahalli Jagadeesh and Kumar (2019), was used to obtain the BD spans. The software was set to commence the task with a series of three digits. A sequence of random digits was presented with an inter-stimulus-interval of 1 second. After the last digit in the sequence is presented, a new window appeared wherein the participant used the number pad of the computer to type-in the sequence in the reverse order. Participants were also instructed to fill in the sequence with the digit 9 in case they forgot a digit in the sequence. The participants had a maximum of 30 seconds to type-in their responses. With each correct response/sequence, the number of digits in the next sequence (span length) was increased by one, whereas with a wrong response, the span length in the following sequence was reduced by one. This adaptive procedure was carried out for a total of six reversals (from correct to wrong and vice-versa). The first two reversals were discarded, and the means of the last four reversals was taken to obtain the BD spans.

As mentioned earlier, the participants were instructed to verbalise their rehearsal. The primary aim of the current study was to observe if 'language of rehearsal' resulted in significant word-length effects (better performances in the language whose digits are shorter in length). Therefore, BD spans were measured under three rehearsal instructions – (i) No instruction regarding the language of rehearsal

Table 1: Mean responses for the different relevant sections/questions of the LEAP-Q

Parameter	Kannada	English
Exposure to language (%)	65.20	34.8
Choice of language to read (%)	29.37	70.63
Choice of language to speak (%)	67.5	32.5
Age of acquisition (in years)	Since birth	5.0
Age of fluency of speaking (in years)	4.62	12.16
Age of fluency of reading (in years)	10.66	11.16
Proficiency (mean of three sections)	9.15	8.15
Language of using digits	5.62	4.38

Note: Comparisons are made across Kannada (Native language) and English (Second language). The parameter 'language of using digits' was not a part of the LEAP-Q but was additionally included especially for this study.

(NI), (ii) Instructed to rehearse in Kannada (RK), and (iii) Instructed to rehearse in English (RE). The NI condition acted as the control condition and was always the first condition to be tested for all participants. Here, no instructions were given regarding the language of rehearsal during this condition. The NI condition was performed first to ensure that participants did not develop a bias towards/against rehearsal in either Kannada or English. However, all participants were explicitly instructed to rehearse overtly. It should be noted, here, that for all the three rehearsal conditions, the stimuli were presented only in the Kannada language. This ensured that the language of stimulus presentation did not act as an additional variable and the only difference between the three conditions was the language of rehearsal.

It was observed that, in the NI condition, a significant proportion of the participants (16 out of 24) rehearsed in Kannada – the language in which the stimuli were presented. For the RK and RE conditions, specific instructions were given to rehearse in Kannada and English, respectively. The order of testing the second and third conditions was randomised to avoid order effects.

RESULTS

We used the JASP (Version 0.8.6) software package to perform all statistical analyses (JASP Team, 2018). The results of both the LEAP-Q and the BD span scores were analysed. We first examined the results from the LEAP-Q. Table 1 shows detailed information about the different relevant sections of the questionnaire. From the table, it can be observed that the mean proficiency scores (mean of speaking, understanding and reading sections) for Kannada (M = 9.15, SD = 0.62) are higher than English (M = 8.15, SD = 0.61). A paired t-test confirmed that proficiency in Kannada was significantly higher than English [t=5.39, p<0.001, d=1.1]. Further, we performed correlational analyses between some of the parameters obtained from the questionnaire – mean proficiency scores in Kannada, mean proficiency scores in English, percentage of English usage while speaking, and the percentage of usage of English or Kannada digits in conversation (rows seven, three and eight respectively in table 1). The correlational analyses were done to observe if proficiency in either Kannada or English had any impact on the usage digits in either language. Analyses revealed no significant correlation between any of the four parameters.

Subsequently, we analysed the results of the BD span under the different rehearsal conditions. Figure 1 shows the means and (one) standard deviation of the BD span scores across the three instruction conditions. Figure 1 shows that the mean BD span for the RE condition (M = 6.78, SD = 0.74) was higher than both the RK (M = 5.99, SD = 0.92) and NI (M = 6.17, SD = 0.88) rehearsal conditions. We used a one-way Repeated Measures Analysis of Variance (RM-ANOVA) to explore the statistical significance of these mean differences. RM-ANOVA revealed a significant main effect of rehearsal condition [F (2, 46) = 14.233, p < 0.001, $\eta_p{}^2$= 0.382]. Post-hoc pairwise comparisons (adjusted for multiple comparisons using Bonferroni's correction) showed that the RE condition resulted in significantly higher BD span scores than both RK [t=-5.56, p<0.001, d=-1.131] and NI [t=-3.52, p=0.005, d=-0.719] conditions. There was no statistically significant difference between the RK and NI conditions [t=1.25, p=0.67, d=-1.25]. We also performed correlational analyses between the mean proficiency scores for both Kannada as well as English languages and the BD span scores across the three conditions. It was observed that there were no significant correlations between any of the conditions considered. This indicates that the proficiency in Kannada or English language did not influence the performance on BD span scores across any of the rehearsal conditions.

DISCUSSION

In this study, we explored if rehearsals in a language whose digits are shorter in length results in improved BD span scores. We measured BD spans on bilingual participants who were explicitly instructed to rehearse overtly in either Kannada (longer digit lengths) or English language (shorter digit lengths), even though the stimuli were presented only in Kannada. A 'No Instruction' condition, where they were not given any instructions regarding the language of rehearsal acted as a control condition. As hypothe-

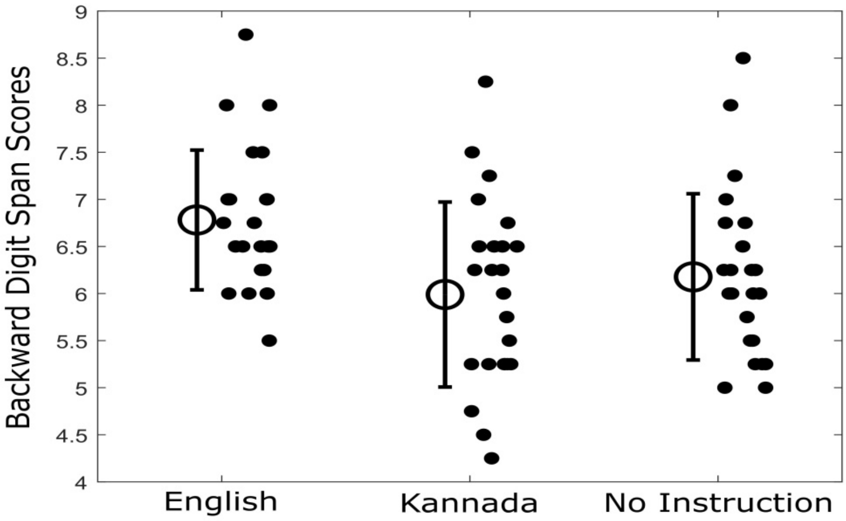

Figure 1: Means and (One) Standard Deviations of the Backward Digit Span scores across the three Instruction conditions. Note: The filled circles, next to the error bars, indicate the individual data points of the participants.

sised, we observed that rehearsal in English resulted in significantly longer BD spans than rehearsal in Kannada. Furthermore, there was no association between the BD spans and the participants' proficiency in either Kannada or English languages.

Previous studies have shown that languages with shorter word-durations result in greater WM spans (Mattys et al., 2017; Shebani et al., 2005; Stigler et al., 1986; Van De Vijver, 2015). Studies have also shown bilinguals gain an advantage when the stimuli are presented in the language with shorter word durations (Brown & Hulme, 1995; Cheung & Kemper, 1994; Ellis & Hennelly, 1980; Hoosain, 1979). These studies have shown that the language of stimulus presentation influences the WM span in bilingual participants. Our study extends these findings and shows that even rehearsal in the language with shorter word length leads to improvement in the WM scores.

The cognitive processes used in the rehearsal strategies are suggested to both influence the WM task performance and result in large individual variations (Baddeley, 2000; Hilbert, Nakagawa, Puci, Zech, & Buhner, 2015; McNamara & Scott, 2001). The results of our study provide further evidence that different rehearsal strategies can influence WM task performance. Additionally, we observed that, when no instructions were given regarding the language of rehearsal (NI condition), 16 out of 24 participants rehearsed in Kannada (the language of stimulus presentation). This is in spite of the observation that both Kannada and English digits were used equally in regular communication by the participants (self-rated). They also rated themselves to have at least 'good' proficiency in English, on average. However, the statistical analyses showed no correlation between the proficiencies in the two languages and BD span scores in any of the three rehearsal conditions. This indicates that it is the rehearsal strategy, and by extension, the word-length effect, that drives the result and not the proficiency and/or frequency of usage of a particular language.

In previously reported studies, typically, word-length effect reflects the effect of stimulus duration (both in terms of the number of syllables and time taken for articulation) on WM performance (Neath & Nairne, 1995). That is, word-length effects are driven by stimulus-related properties (Ellis & Hennelly, 1980). However, we hypothesised that word-length effects could also be related to internal cognitive strategies adopted by the participants. Our finding that rehearsal in English results in significantly better BD spans score, in comparison to Kannada, demonstrates that the word-length effect is observed even in the selection of the most appropriate rehearsal strategy.

Furthermore, it has been suggested that, in bilinguals, irrespective of the language of stimulus presentation, the lexical representations in both languages are automatically activated (Dijkstra & van Heuven, 2002). Since it is not possible to produce the sounds in both languages, the speaker selects the most appropriate language (Ratiu & Azuma, 2015). This selection involves an adaptive selection of task-relevant language for processing and further comprehension, along with inhibition of the task-irrelevant language (Green & Abutalebi, 2013). We presume it is during this selection and inhibition of the two languages that the role of strategy comes in. We believe that, over the duration of the task, a listener fine-tunes and updates his strategy to what suits best to that context. Individuals who use the most efficient strategies for the given context can often recall more items than those who cannot (Turley-Ames & Whitfield, 2003).

Cross-modal rehearsal strategies have already been reported (Rayner & Riding, 1997). Therefore, it is possible that some of the participants can use an across-language rehearsal strategy when the situation is appropriate. This indeed was the case in our study. A small number of participants, eight out of 24, reported to have rehearsed in English, despite the stimuli being presented in Kannada. This provides evidence that across-language rehearsal is certainly a strategy used by bilinguals. Although it has been suggested that language-switching comes at the cost of additional cognitive-linguistic processing load (Alsaigh & Kennison, 2017; Boukadi, Davies, & Wilson, 2015; Olson, 2017), the results of our experiment provide evidence that language-switching can be beneficial when used as a rehearsal strategy due to the word length effects.

CONCLUSIONS

In this study, we provide evidence that the word length effects can also be observed when rehearsals are done in different languages. Rehearsal in a language with shorter word lengths leads to better WM scores, as measured on a BD span task. The greater WM performance, observed only in bilinguals, could also be associated with better metalinguistic awareness both their proficient languages. It is, therefore, essential to consider the bilingual effects on WM while using backward span tasks in bilingual research. Considering these aspects, it is recommended, to have different normative values for bilingual/multilingual populations (like India). It is also recommended to use clear instructions regarding the language of rehearsal while measuring BD spans in bilingual participants. This will likely ensure homogeneity of data in such populations. Also, further studies are warranted to understand the use of such across-language rehearsal strategies while using other, more complex, tests of WM such as listening span, operation span, etc. Understanding such strategies in more difficult-to-listen scenarios is also warranted. This would help generalise the across-language rehearsal strategies to a more ecological and realistic scenario than the simple backward span task.

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REFERENCES

American National Standard Institute. (2003). Maximum permissible ambient noise levels for audiometric test rooms (Rev. ed) (ANSI S3.1-1999).

Alsaigh, T., & Kennison, S. M. (2017). Second language interference during first language processing by Arabic-English bilinguals. *Frontiers in Psychology, 8*, 1956. https://doi.org/10.3389/fpsyg.2017.01956

Anderson, J. A. E., Mak, L., Keyvani Chahi, A., & Bialystok, E. (2018). The language and social background questionnaire: Assessing degree of bilingualism in a diverse population. *Behavior Research Methods, 50*(1), 250–263. https://doi.org/10.3758/s13428-017-0867-9

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? Trends in Cognitive Sciences, 4(11), 417–423. https://doi.org/10.1016/S1364-6613(00)01538-2

Baddeley, A. D. (2000b). The phonological loop and the irrelevant speech effect: Some comments on Neath (2000). *Psychonomic Bulletin and Review, 7*(3), 544–549. https://doi.org/10.3758/BF03214369

Baddeley, A. D. (2003). Working memory and language: An overview. *Journal of Communication Disorders, 36*(3), 189–208. https://doi.org/10.1016/S0021-9924(03)00019-4

Baddeley, A. D. (2010). Working memory. *Current Biology, 20*(4), R136-40. https://doi.org/10.1016/j.cub.2009.12.014

Baddeley, A. D., Buchanan, M., & Thomson, N. (1975). Word Length and the Structure of Short-Term Memory. *Journal of Verbal Learning and Verbal Behaviour, 14*(6), 575–589.

Bailey, H., Dunlosky, J., & Hertzog, C. (2009). Does Differential Strategy Use Account for Age-Related Deficits in Working-Memory Performance? *Psychology and Aging, 24*(1), 82–92. https://doi.org/10.1037/a0014078

Basavanahalli Jagadeesh, A., & Kumar U, A. (2019). Effect of informational masking on auditory working memory: role of linguistic information in the maskers. *Hearing, Balance and Communication, 17*(4), 270–279. https://doi.org/10.1080/21695717.2019.1630980

Boukadi, M., Davies, R. A. I., & Wilson, M. A. (2015). Bilingual lexical selection as a dynamic process: Evidence from Arabic-French bilinguals. *Canadian Journal of Experimental Psychology, 69*(4), 297–313. https://doi.org/10.1037/cep0000063

Brown, G. D. A., & Hulme, C. (1995). Modeling Item Length Effects in Memory Span: No Rehearsal Needed? *Journal of Memory and Language.* https://doi.org/10.1006/jmla.1995.1027

Campoy, G., & Baddeley, A. (2008). Phonological and semantic strategies in immediate serial recall. *Memory, 16*(4), 329–340. https://doi.org/10.1080/09658210701867302

Cheung, H., & Kemper, S. (1994). Recall and Articulation of English and Chinese Words Under Memory Preload Conditions. *Language and Speech,* *37*(2), 147–161. https://doi.org/10.1177/002383099403700203

Chincotta, D., Hyönä, J., & Underwood, G. (1997). Eye fixations, speech rate and bilingual digit span: Numeral reading indexes fluency not word length. *Acta Psychologica, 97*(3), 253–275. https://doi.org/10.1016/S0001-6918(97)00031-0

Conrad, M., Recio, G., & Jacobs, A. M. (2011). The time course of emotion effects in first and second language processing: A cross cultural ERP study with German-Spanish bilinguals. *Frontiers in Psychology,* 2(DEC), 1–16. https://doi.org/10.3389/fpsyg.2011.00351

Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5*(03), 175–197. https://doi.org/10.1017/S1366728902003012

Dunn, G., Gaudia, L., Lowenherz, J., & Barnes, M. (1990). Effects of reversing digits forward and digits backward and strategy use on digit span performance. *Journal of Psychoeducational Assessment, 8*(1), 22–33.

Ellis, N. C. (1992). Linguistic Relativity Revisited: The Bilingual Word-length Effect in Working Memory During Counting, Remembering Numbers, and Mental Calculation. *Advances in Psychology, 83*, 137–155. https://doi.org/10.1016/S0166-4115(08)61492-2

Ellis, N. C., & Hennelly, R. A. (1980). A bilingual word-length effect: Implications for intelligence testing and the relative ease of mental calculation in Welsh and English. *British Journal of Psychology, 71*(1), 43–51. https://doi.org/10.1111/j.2044-8295.1980.tb02728.x

Friesen, D. C., & Bialystok, E. (2012). Metalinguistic Ability in Bilingual Children: The Role of Executive Control. *Rivista Di Psicolinguistica Applicata, 12*(3), 47–56.

Glanzer, M. (1976). Intonation grouping and related words in free recall. *Journal of Verbal Learning and Verbal Behavior, 15*(1), 85–92. https://doi.org/10.1016/S0022-5371(76)90009-8

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology, 25*(5), 515–530. https://doi.org/10.1080/20445911.2013.796377

Henry, L. A. (2012). The Working Memory Model. In *The Development of Working Memory in Children* (pp. 1–36). London: SAGE Publications Ltd. https://doi.org/10.4135/9781446251348.n1

Hilbert, S., Nakagawa, T. T., Puci, P., Zech, A., & Buhner, M. (2015). The digit span backwards task: Verbal and visual cognitive strategies in working memory assessment. *European Journal of Psychological Assessment, 31*(3), 174–180. https://doi.org/10.1027/1015-5759/a000223

Hoosain, R. (1979). Forward and backward digit span in the languages of the bilingual. *Journal of Genetic Psychology, 135*(2), 263–268. https://doi.org/10.1080/00221325.1979.10534079

JASP Team. (2018). JASP (Version 0.8.6) [Computer software]. Retrieved from https:// jasp-stats.org/ on 02-03-2019.

Kaushanskaya, M., Blumenfeld, H. K., & Marian, V. (2019). The Language Experience and Proficiency Questionnaire (LEAP-Q): Ten years later. *Bilingualism: Language and Cognition,* (July), 1–6. https://doi.org/10.1017/S1366728919000038

Malda, M., Vijver, F. J. R. Van De, Srinivasan, K., Transler, C., Sukumar, P., & Rao, K. (2008). Adapting a cognitive test for a different culture : An illustration of qualitative procedures. *Psychology Science Quarterly, 50*(4), 451–468.

Marian, V., Blumfield, H., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing Language Profiles in Bilinguals and Multilinguals. *Journal of Speech, Language, and Hearing Research, 50*(August 2007), 940–967. https://doi.org/10.1044/1092-4388(2007/067)

Maruthy, S. and Kumar A. U. (2013). Development of Auditory-cognitive training module. *AIISH research fund project.*

Mattys, S. L., Baddeley, A. D., & Trenkic, D. (2017). Is the superior verbal memory span of Mandarin speakers due to faster rehearsal? *Memory and Cognition,* (1974), 1–9. https://doi.org/10.3758/s13421-017-0770-8

McNamara, D. S., & Scott, J. L. (2001). Working memory capacity and strategy use. *Memory & Cognition, 29*(1), 10–17. https://doi.org/10.3758/BF03195736

Nag, S., & Snowling, M. J. (2011). Cognitive profiles of poor readers of Kannada. *Reading and Writing, 24*(6), 657–676. https://doi.org/10.1007/s11145-010-9258-7

Nag, S., Treiman, R., & Snowling, M. J. (2010). Learning to spell in an alphasyllabary: The case of Kannada. *Writing Systems Research, 2*(1), 41–52. https://doi.org/10.1093/wsr/wsq001

Naveh-Benjamin, M., & Ayres, T. J. (1986). Digit Span, Reading Rate, and Linguistic Relativity. *The Quarterly Journal of Experimental Psychology Section, 38A*(4), 739–751. https://doi.org/10.1080/14640748608401623

Neath, I., & Nairne, J. S. (1995). Word-length effects in immediate memory: Overwriting trace decay theory. *Psychonomic Bulletin & Review, 2*(4), 429–441. https://doi.org/10.3758/BF03210981

Olson, D. J. (2017). Bilingual language switching costs in auditory comprehension. *Language, Cognition and Neuroscience, 32*(4), 494–513. https://doi.org/10.1080/23273798.2016.1250927

Prior, A., & Gollan, T. H. (2011). Good language-switchers are good task-switchers: Evidence from Spanish-English and Mandarin-English bilinguals. *Journal of the International Neuropsychological Society, 17*(4), 682–691. https://doi.org/10.1017/S1355617711000580

Ratiu, I., & Azuma, T. (2015). Working memory capacity: Is there a bilingual advantage? *Journal of Cognitive Psychology, 27*(1), 1–11. https://doi.org/10.1080/20445911.2014.976226

Rayner, S., & Riding, R. (1997). Towards a Categorisation of Cognitive Styles and Learning Styles. *Educational Psychology, 17*(1–2), 5–27. https://doi.org/10.1080/0144341970170101

Rupela, V., Manjula, R., & Velleman, S. L. (2010). Phonological processes in Kannada-speaking adolescents with Down syndrome. *Clinical Linguistics and Phonetics, 24*(6), 431–450. https://doi.org/10.3109/02699200903450164

Shebani, M. F. A., Van De Vijver, F. J. R., & Poortinga, Y. H. (2005). A strict test of the phonological loop hypothesis with Libyan data. *Memory and Cognition, 33*(2), 196–202. https://doi.org/10.3758/BF03195308

Stigler, J. W., Lee, S., & Stevenson, H. W. (1986). Digit memory in Chinese and English : Evidence for a temporally limited store. *Cognition, 23,* 1–20.

Ter Kuile, H., Veldhuis, M., Van Veen, S. C., & Wicherts, J. M. (2011). Bilingual education, metalinguistic awareness, and the understanding of an unknown language. *Bilingualism, 14*(2), 233–242. https://doi.org/10.1017/S1366728910000258

Turley-Ames, K. J., & Whitfield, M. M. (2003). Strategy training and working memory task performance. *Journal of Memory and Language, 49*(4), 446–468. https://doi.org/10.1016/S0749-596X(03)00095-0

Van De Vijver, F. J. R. (2015). Methodological aspects of cross-cultural research. In M. Gelfand, Y. Hong, & C. Y. Chiu (Eds.), *Handbook of advances in culture & psychology* (Vol. 5, pp. 101–160). New York, NY, US: Oxford University Press.

Wilde, N. J., Strauss, E., & Tulsky, D. S. (2004). Memory span on the wechsler scales. *Journal of Clinical and Experimental Neuropsychology, 26*(4), 539–549. https://doi.org/10.1080/13803390490496605