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Backward and forward serial recall across modalities: An individual differences perspective[☆]

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A B S T R A C T

The correlation between Digit Span Forward (DSF) and Digit Span Backward (DSB) scores from the Wechsler scales is moderate ($r \approx .50$), but surprisingly small given the highly similar nature of the tests. To-date, little research has examined the association between forward and backward recall across other stimulus modalities (e.g., words, shapes). Furthermore, some experimental research suggests that performance on verbal backward span may be affected differentially by visuospatial ability. Consequently, the purpose of this investigation was to evaluate the factorial validity of forward and backward span across three stimulus modalities: single digits, three-syllable words, and visual shapes. Additionally, a mental rotation test was administered to the participants ($N = 211$). Based on a factor analysis, four factors were identified: visuospatial memory span, three-syllable word span, DSF, and DSB. The DSF and DSB factors were related moderately at $r = .40$. Finally, visuospatial ability was not observed to relate to DSB uniquely ($\lambda = .07$; $BF_{01} = 8.65$). The results suggest that there may be a process distinction that is unique to the recall of digits in forward and backward formats. However, the process distinction does not appear to be visuospatial ability.

1. Introduction

Digit Span Forward (DSF) and Digit Span Backward (DSB) are very similar tasks, however, they share approximately only 45% of their true score variance (Gignac, 2015; Wechsler, 2008). Theoretically, it has been contended that DSF and DSB tap partly different psychological processes. Specifically, while DSF has been proposed to involve storage and retrieval processes, DSB has been hypothesized to involve additional executive processes (Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000). It has also been proposed that DSB may draw more heavily upon visuospatial processing, in comparison to DSF (Reynolds, 1997).

Although a relatively substantial amount of research has supported the psychometric distinction between forward and backward span with digits, little differential psychology research has been conducted with other types of stimuli. Consequently, the purpose of this investigation was twofold. First, to investigate whether the psychometric distinction between forward span and backward span extends to test content modalities other than digits (i.e., three-syllable words and visual shapes). Additionally, the hypothesis that individual differences in visuospatial ability may differentially relate to DSF and DSB was tested.

1.1. Background

In the Wechsler scales (e.g., WAIS-IV; Wechsler, 2008), the Digit Span subscale involves the oral presentation of digits to the participant at 1 s intervals. The participant is requested to recall as many of the digits as possible in a certain order. In the forward version of the test, the participant is instructed to recall the digits in the order with which they were presented. In the backward version of the test, the participant is instructed to recall the digits in the reverse order with which they were presented. A non-negligible amount of research has been conducted on the distinction between DSF and DSB, particularly within the context of short-term memory capacity (STMC) and working memory capacity (WMC; Conway & Kovacs, 2013).

Theoretically, measures of STMC are considered to involve storage and retrieval over a brief period of time (seconds). By contrast, measures of WMC require processing parallel to storage and retrieval (Conway et al., 2005; Redick et al., 2012). For example, WMC tasks have been suggested to require the coordination and transformation of information (Oberauer et al., 2000). A classic measure of WMC is the reading span task, which requires one to read a list of sentences and

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remember words presented at the end of each sentence (Daneman & Carpenter, 1980). Letter-number sequencing, which consists of a series of items with alternating digits and letters presented orally or visually, is also considered a measure of WMC (Gold, Carpenter, Randolph, Goldberg, & Weinberger, 1997). In a manner similar to letter-number sequencing, some researchers have classified DSF a measure of STMC and DSB a measure of WMC (e.g., Oberauer et al., 2000; but see Colom, Shih, Flores-Mendoza, & Quiroga, 2006). Theoretically, DSB may be considered a measure of WMC, as it requires the simultaneous maintenance of the digits in memory and the reordering of the digits.

1.2. Serial Recall Across Modalities

In comparison to digits, there is much less research on the psychometric distinction between forward and backward serial recall of stimuli from other modalities (e.g., multi-syllable words, visual shapes). An occasionally observed exception is the application of the spatial memory Corsi-Block Tapping Task (Corsi, 1972), which has been modified for application in forward and backward recall formats. For example, Kessels, van den Berg, Ruis, and Brands (2008) administered the Corsi Task in forward and backward formats, as well DSF and DSB, to a sample of 246 healthy adults. Kessels et al. reported that DSF and DSB correlated at $r = .45$. Additionally, Corsi forward and backward tasks correlated at $r = .38$. Thus, forward and backward spatial memory may be only moderately related in a manner similar to digits. Unfortunately, Kessels et al. did not conduct an item-level factor analysis to investigate more directly whether the forward and backward Corsi task items represented two dimensions. Thus, it remains to be determined whether forward and backward spatial stimuli measure a single dimension of memory span or two dimensions.

Appealing to the broader area of STMC and WMC multi-modality research, there is some indirect evidence to suggest that forward and backward span may broadly yield separate factors. For example, Kane et al. (2004) estimated the latent variable association between STMC and WMC across verbal and spatial modalities at $r = .79$ ($r^2 = .62$) and $r = .89$ ($r^2 = .79$), respectively. Although neither correlation was so large as to suggest redundancy between STMC and WMC, the spatial latent variable correlation was statistically significantly larger than the verbal latent variable correlation, $\Delta r = .10$, $z = -3.78$, $p < .001$ (95%CI: .05/.16).[1] A very similar effect was reported by Alloway, Gathercole, and Pickering (2006), where the latent variable association between STMC and WMC across verbal and spatial modalities was estimated at $r = .68$ ($r^2 = .46$) and $r = .78$ ($r^2 = .61$), respectively. Again, although neither correlation was so large as to suggest redundancy, the spatial latent variable correlation was statistically significantly larger than the verbal latent variable correlation, $\Delta r = .10$, $z = 4.06$, $p < .001$ (95%CI: .05/.15).

With respect to the specific issue of forward and backward span, the results of Kane et al. (2004) and Alloway et al. (2006) are only suggestive, as they included a diversity of STMC and WMC measures, rather than comparable forward and backward span tests. Nonetheless, the results suggest substantially less unique variance associated with spatial STMC and WMC span tasks, in comparison to verbal STMC and WMC span tasks. Thus, it is possible that the surprisingly small span forward and span backward correlation may not extend to more visuospatial stimuli.

1.3. Serial Recall and Visuospatial Ability

The additional requirement of WMC tasks to manipulate information for successful completion has been suggested to involve additional processing, namely executive and attentional processes (Engle & Kane, 2004; Gathercole, Pickering, Ambridge, & Wearing, 2004; Lehto, 1996; Oberauer et al., 2000; Waters & Caplan, 2003). The recruitment of such cognitive capacities may partly explain why scores between DSF and DSB share < 50% of their true score variance. From a neuropsychological perspective, Reynolds (1997), who viewed DSF and DSB as clinically distinct scores, hypothesized that, "[DSB] may also invoke, for many individuals, visuospatial imaging processes even for ostensibly verbal material such as letters" (p. 39). To our knowledge, little differential psychology research that has evaluated Reynolds' (1997) hypothesis. However, there is some experimental research that does support the possibility that visuospatial ability may play a unique role in the execution of DSB.

For example, Li and Lewandowsky (1995) conducted a series of experiments where participants completed a serial letter recall task in both forward and backward formats. In one of the Li and Lewandowsky (1995) experiments, the presentation of the letters on the screen varied across two conditions: (1) always in the centre of the screen; and (2) random presentation on the screen. Random presentation of the letters on the screen affected performance negatively for backward serial recall, but not forward serial recall.

In another investigation, St Clair-Thompson and Allen (2013) conducted a series of forward and backward span experiments with a visuospatial concurrent task. In one particular experiment, the visuospatial concurrent task was administered during the recall phase of the digit span forward and backward tasks. The visuospatial concurrent task was found to affect performance negatively on the DSB task, but not the DSF task. Thus, in light of the experimental work of Li and Lewandowsky (1995) and St. Clair-Thompson and Allen, it may be suggested that visuospatial cognitive ability may play a distinctive role in the execution of forward and backward serial recall.

1.4. Study Purpose

In light of the above, the purpose of this investigation was twofold. First, to evaluate the factorial validity of DSF and DSB within the broader context of serial recall tasks of a very similar nature: specifically, three-syllable words in forward and backward formats (i.e., word span) and visual shapes in forward and backward formats (i.e., visual span). Secondly, to test the hypothesis that visuospatial ability may be uniquely related to DSB.

2. Method

2.1. Sample

Psychology undergraduates ($N = 211$; 68% female) who spoke English as a first language and received partial course credit for participation (age $M = 19.8$; $SD = 2.9$; range 17–35). The original sample contained an additional 12 participants over the age of 35 years. However, as age-based test norms were not available, they were omitted from the final sample.

2.2. Measures

2.2.1. Digit span forward and backward

The Digit span subscale from the WAIS–IV (Wechsler, 2008). The internal consistency reliabilities (omega, ω; Raykov, 2001) were: forward $\omega = .74$ and backward $\omega = .79$.

2.2.2. Word span forward and backward

Three-syllable word tests in forward and backward formats. The words were sourced from La Pointe and Engle (1990). Participants were presented via audio a series of three-syllable words with a 1 s pause between each word. The participants were presented with two trials per series of words progressively from two words up to a maximum of nine words (termination rule: two incorrect trials in a row). Each trial was scored 0/1 (forward max: 18; backward max: 16). The test was

[1] Based on our application of a method provided by Weaver and Wuensch (2013).