Cognitive Psychology 71 (2014) 1–26

Contents lists available at ScienceDirect

Cognitive Psychology

journal homepage: www.elsevier.com/locate/cogpsych

Working memory and fluid intelligence: Capacity, attention control, and secondary memory retrieval

Nash Unsworth [a,*], Keisuke Fukuda [b], Edward Awh [a], Edward K. Vogel [a]

[a] Department of Psychology, University of Oregon, United States
[b] Department of Psychology, Vanderbilt University, United States

ARTICLE INFO

Article history:
Accepted 22 January 2014
Available online 14 February 2014

Keywords:
Working memory
Fluid intelligence

ABSTRACT

Several theories have been put forth to explain the relation between working memory (WM) and gF. Unfortunately, no single factor has been shown to fully account for the relation between these two important constructs. In the current study we tested whether multiple factors (capacity, attention control, and secondary memory) would collectively account for the relation. A large number of participants performed multiple measures of each construct and latent variable analyses were used to examine the data. The results demonstrated that capacity, attention control, and secondary memory were uniquely related to WM storage, WM processing, and gF. Importantly, the three factors completely accounted for the relation between WM (both processing and storage) and gF. Thus, although storage and processing make independent contributions to gF, both of these contributions are accounted for by variation in capacity, attention control and secondary memory. These results are consistent with the multifaceted view of WM, suggesting that individual differences in capacity, attention control, and secondary memory jointly account for individual differences in WM and its relation with gF.

1. Introduction

Complex working memory (WM) span tasks such as reading and operation span have been shown to be important predictors of a number of higher-order and lower-order cognitive processes. In these

* Corresponding author. Address: Department of Psychology, University of Oregon, Eugene, OR 97403, United States.
E-mail address: nashu@uoregon.edu (N. Unsworth).

http://dx.doi.org/10.1016/j.cogpsych.2014.01.003
0010-0285/

tasks to-be-remembered items are interspersed with some form of distracting activity such as reading sentences or solving math problems. Based on these complex span tasks, WM has been shown to predict performance on a number of higher-order cognitive tasks including reading comprehension (Daneman & Carpenter, 1980), vocabulary learning (Daneman & Green, 1986), and performance on the SATs (Turner & Engle, 1989). Likewise, WM span tasks have been shown to predict performance on a number of attention and inhibition tasks (Engle & Kane, 2004; McVay & Kane, 2012; Unsworth & Spillers, 2010a), as well as predict performance on a number of secondary or long-term memory tasks (Unsworth, 2010; Unsworth, Brewer, & Spillers, 2009). Furthermore, these tasks have been shown to predict important phenomena such as early onset Alzheimer's (Rosen, Bergeson, Putnam, Harwell, & Sunderland, 2002), life-event stress (Klein & Boals, 2001), aspects of personality (Unsworth, Miller, Lakey, Young, Meeks & Campbell, 2009), susceptibility to choking under pressure (Beilock & Carr, 2005), and stereotype threat (Schamader & Johns, 2003).

It is clear from a number of studies that WM has substantial predictive power in terms of predicting performance on a number of measures. In particular, the relation between WM and fluid intelligence has received a considerable amount of attention. Fluid intelligence (gF), which is the ability to solve novel reasoning problems, has been extensively researched and shown to correlate with a number of important skills such as comprehension, problem solving, and learning (Cattell, 1971), and has been found to be an important predictor of a number of real world behaviors including performance in educational settings (Deary, Strand, Smith, & Fernandes, 2007) as well as overall health and mortality (Gottfredson & Deary, 2004). Beginning with the work of Kyllonen and Christal (1990) research has suggested that there is a strong link between individual differences in WM and gF. In particular, this work suggests that at an individual task level measures of WM correlate with gF measures around .45 (Ackerman, Beier, & Boyle, 2005) and at the latent level WM and gF are correlated around .72 (Kane, Hambrick, & Conway, 2005). Thus, at a latent level WM and gF seem to share approximately half of their variance. However, the reason for this predictive power remains elusive. The current study examines the extent to which multiple factors (capacity, attention control, and secondary memory) rather than a single factor account for the relation between WM and gF.

Closely following the ideas of Baddeley and Hitch (1974), one of the first theories put forth to explain individual differences in WM and its relation with higher-order cognition suggested that individuals have a fixed pool of resources which they can allocate to both processing and storage in complex span tasks. In this view complex span tasks measure the dynamic tradeoff between processing and storage and that as the processing component becomes more taxing, there are fewer resources left over to store the to-be-remembered (TBR) items (Case, Kurland, & Goldberg, 1982; Daneman & Carpenter, 1980; Daneman & Tardif, 1987; Just & Carpenter, 1992). Thus, the storage score provides an index of how efficiently an individual can process and store information. If a person can efficiently process a lot of information then there will be adequate resources available for storage and hence a high storage score. However, if a person is less efficient at processing information, most of their resources will be devoted to the processing task, leaving few resources available for storage and hence a low storage score. Furthermore, this view argues that the reason WM (as measured by complex span tasks) predicts higher-order cognition so well is because WM represents the dynamic tradeoff between processing and storage which is needed in many complex cognitive tasks including measures of gF. As such, resource sharing is thought to underlie individual differences in WM and account for their relation with higher-order cognition. Problems with resource sharing views are findings that processing and storage can make independent contributions to task performance and to the correlation with measures of mental abilities (Bayliss, Jarrold, Gunn, & Baddeley, 2003; Duff & Logie, 2001; Logie & Duff, 2007; Unsworth, Redick, Heitz, Broadway & Engle, 2009; Waters & Caplan, 1996). That is, although prior work has shown that measures of processing are in fact related to measures of higher-order cognition including measures of gF, WM storage scores still predicted higher-order cognition even after controlling for processing (Bayliss et al., 2003; Engle, Cantor, & Carullo, 1992; Friedman & Miyake, 2004; Unsworth, Heitz, Schrock, & Engle, 2005; Unsworth, Redick, et al., 2009). Thus, although the relation between processing and storage is important, prior research has demonstrated that variation in processing efficiency or resource sharing does not fully account for the relation between WM (particularly WM storage) and gF.

More recent theories of WM have moved away from the idea that resource sharing between processing and storage is what is important, and have instead proposed that individual differences in WM