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Individual differences in self-initiated processing at encoding and retrieval: A latent variable analysis

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Short article

Individual differences in self-initiated processing at encoding and retrieval: A latent variable analysis

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The current study examined individual differences in self-initiated processing (SIP) in memory tasks. Participants performed four memory tasks that varied the amount of SIP required at encoding, retrieval, or both as well as cognitive ability measures. It was found that the correlation between recall performance and cognitive abilities changed as a function of the amount of SIP required. Additionally, it was found that although both free and cued recall measures accounted for variance in cognitive abilities, only the free recall accounted for unique variance in cognitive abilities. It is suggested that the predictive power of a task is determined in part based on the amount of SIP required.

Keywords: Individual differences; Self-initiated processing; Recall.

In general, explicit memory tasks like free recall, serial recall, cued recall, and even recognition probably draw upon many of the same general set of component processes. Consistent with previous work these component processes can be subdivided into two general types, which probably fall on a continuum of processes: automatic/associative and controlled/strategic (Jacoby, 1991; Moscovitch, 1992). For instance, in Moscovitch's (1992) working with memory model associative processes occur when the cue that is presented to the system is sufficient to generate the desired information. Strategic processes, however, are utilized when the cue does not automatically generate the desired information, but rather only provides partial information that can be used to engage in a more elaborative strategic search of memory.

Accordingly performance on a number of memory tasks is driven by both associative processes and strategic processes. Furthermore, there are several component control processes that are important for successful task performance, and hence successful remembering, which operate at both encoding and retrieval. These component control processes include organizing information at encoding, engaging in elaborative rehearsal, selecting cues for strategic search, and monitoring the outputs of the search. In many memory tasks most, if not all, of these control processes will be needed for accurate performance. Problems or

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deficits in any one of these component control processescan lead to poor performance on a number of memory tasks and hence greater forgetting. Furthermore, there is probably a large amount of individual variation in the efficiency of these component processes, which then leads to large variation in performance on a number of memory tasks.

Many of these component control processes are particularly important in tasks that require a high degree of what Craik (1983, 1986) has called self-initiated processing (SIP). Craik has argued that memory tasks differ in the amount of SIP that is required for accurate performance. In terms of memory processes Craik has suggested that retrieval is the process of recreating the pattern of activity that was present at encoding. When environmental support is high (i.e., external environment is similar to encoding context) the probability of recreating the pattern is high. However, when environmental support is low (i.e., differences in context, and no cues are provided) retrieval is difficult and requires SIP to reinstate the context.

Like the notion that strategic processes are needed to work with associative processes, Craik's SIP concept suggests that sometimes one must engage in strategic processing when associative processing simply won't cut it. In an attempt to explain why older and younger adults sometimes demonstrate large performance differences on memory tasks and other times demonstrate small to nonexistent differences, Craik (1983) suggested that memory tasks differ in the extent with which SIP are required. Tasks such as free recall where there is little environmental support draw heavily on SIP, whereas tasks such as recognition, where there is a great deal of environmental support, do not require much SIP. Thus, younger and older adults will differ mainly on tasks like free recall, but will show few if any differences in tasks like recognition (e.g., Craik, 1986). Likewise we may expect that individual variation within an age group may be larger on tasks that require more SIP (free recall) than on tasks that require fewer self-initiated processing (recognition).

Integrating the notions of component-processing models and differences in tasks that require SIP suggests that tasks that draw heavily on SIP do so because they require many of the component control processes noted above. Performance on tasks like free recall require that nearly all of the component processes are operating at a high level in order for accurate remembering to occur. Tasks like recognition, however, do not require all of the component processes and thus rely less on SIP. Therefore, the extent to which tasks will demonstrate differential discrimination power in terms of ageing and individual differences relies to a large extent on the proportion of component processes that are needed for accurate performance. Likewise, tasks will demonstrate strong correlations with one another based on the extent to which they rely on the same component processes. Indeed, Johnson (2005) has recently commented that what is important in determining the extent to which tasks will correlate with one another and be useful in determining age and individual differences is the extent to which two tasks require the same constellation of component processes. Thus, tasks that require a great deal of SIP do so because they require the efficiency of multiple component processes, any of which can fail leading to poor performance. Variation in normal healthy individuals, in age, and neuropsychological disturbances in these component processes can then lead to large differences in performance on a number of tasks.

The goal of the present investigation was to examine individual differences in SIP in encoding and retrieval processes in healthy young adults. Specifically, one goal was to examine the extent to which the correlation between performance on a given task and cognitive ability measures would change as a function of the amount of SIP required on that task. That is, Salthouse (2001) suggested that as the amount of SIP required on a task increased, so should the correlation between performance on that task and age. Here this issue is examined for individuals within an age group, and thus instead of examining the correlation between task performance and age, the correlation between task performance and other cognitive abilities (working-memory capacity, WMC, and fluid intelligence, gF) is examined. Similar to

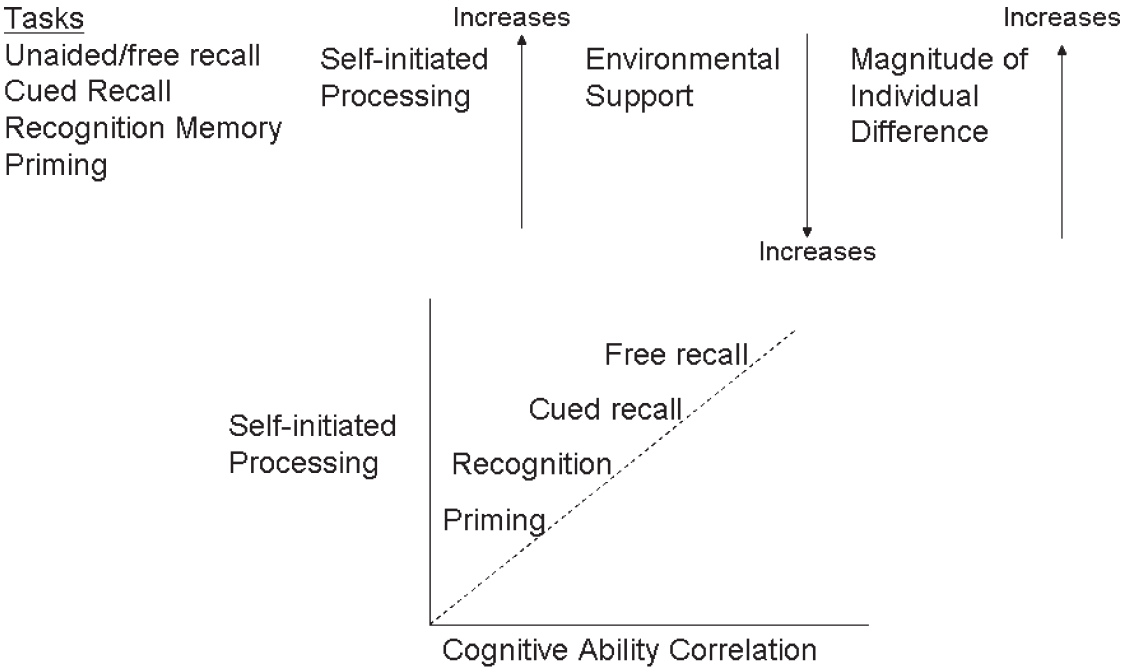

Figure 1. *Schematic of the relation between amount of self-initiated processing, amount of environmental support, and magnitude of systematic individual differences (cognitive ability correlations) adapted from Craik and Grady (2002) and Salthouse (2001).*

Salthouse (2001) it is expected that tasks that require more SIP (free recall) should correlate higher with cognitive ability measures than tasks that require less SIP (cued recall). This overall scheme is depicted in Figure 1. Here it is shown that SIP is required on some tasks more than others, and the amount of SIP required can be compensated by environmental support. Tasks that require a large amount of SIP in the absence of environmental support will lead to larger systematic individual differences than tasks that require fewer SIP.

At the same time, even though the correlations between task performance and cognitive abilities should change as a function of the amount of SIP required, there should still be some SIP required on tasks such as cued recall and recognition, and, thus, there should be some shared variance between these tasks and tasks such as free recall. It should be possible then to extract the shared variance across these tasks (which should reflect the overlap in SIP), and this shared variance should be correlated with cognitive abilities.

This would suggest that there are both shared and unique sources of variance associated with tasks as a function of the amount of SIP. Tasks like free recall should have a good deal of unique variance shared with higher order abilities because these tasks rely on many processes, while tasks like cued recall should share little unique variance with cognitive abilities because they rely on largely the same processes as free recall without the benefit of any additional processes. This would suggest that the predictive power of a task is driven by the amount of SIP that is required, with each task having different relative amounts of both shared and unique influences.

In order to examine the notion of individual differences in SIP, two free recall tasks and two cued recall tasks were used. These tasks were adapted from a study by Craik, Byrd, and Swanson (1987) in which the amount of support at encoding, retrieval, or both was varied. Specifically, participants were given no cues at either encoding or retrieval (free–free), cues at encoding but no cues at retrieval (cued–free), no cues at encoding but cues at retrieval (free–cued), or cues at both encoding and retrieval (cued–cued). Thus, each task differed theoretically in the amount of SIP that was required overall, as well as at encoding or at retrieval with the free–free task requiring the most SIP, the cued–cued task requiring the least amount of SIP, and the two remaining tasks requiring intermediate levels of SIP. Note, that the tasks also differ in other respects other than just amount of SIP, but the current focus is only on the amount of SIP required. Accordingly, this should result in the free–free task demonstrating the largest correlations with cognitive abilities while the cued–cued task should demonstrate the weakest correlations with cognitive abilities. Furthermore, both the free–free task and the cued–cued task should share a substantial amount of variance with each other and with cognitive abilities assuming that they rely on similar control processes, but the free–free task should account for unique variance in cognitive abilities over and above that accounted for by the cued–cued task. Additionally, it should be possible to determine how support at retrieval (which should reduce the amount of SIP required) influences the correlation between the different recall tasks and cognitive abilities. Specifically, tasks where cues were provided at retrieval should correlate more weakly with cognitive abilities than tasks where no cues were provided at retrieval. Finally, given that WMC measures probably require many of the same component control processes as the recall tasks, it should be possible to extract a higher order factor that represents the shared variance across all of the memory tasks, and this factor should be moderately related with gF.

Method

Participants

A total of 137 participants were recruited from the subject pool at the University of Georgia. Participants were between the ages of 18 and 35 years and received course credit for their participation. Each participant was tested in a laboratory session lasting approximately an hour and a half.

Materials and procedure

After signing informed consent, all participants completed the operation span (Ospan) task, the symmetry span (Symspan) task, the reading span (Rspan) task, a brief paper pencil version of the Raven advanced progressive matrices (Raven, Raven, & Court, 1998), a brief paper and pencil verbal analogies test, a version of Thurstone's (1962) Number Series test, and the four recall tasks (free–free, cued–free, free–cued, cued–cued). All tasks were administered in the order listed above.

Tasks

Ospan. Participants solved maths problems while trying to remember an unrelated set of letters. Participants received three trials of each set size, with the set sizes ranging from 3–7. This made for a total of 75 letters and 75 maths problems. Order of set sizes was random for each participant. The score was the number of correct items recalled in the correct position.

Symspan. Participants made symmetry judgements while trying to remember a sequence of red squares presented within a 8 × 8 matrix. Participants received three trials of each set size, with the set sizes ranging from 2–5. This made for a total of 42 squares and 42 symmetry judgement problems. Order of set sizes was random for each participant. The score was the number of correct items recalled in the correct position.

Rspan. Participants judged whether sentences made sense while trying to remember an unrelated set of letters. Participants received three trials of each set size, with the set sizes ranging from 3–7. This made for a total of 75 letters and 75 sentences. Order of set sizes was random for each participant. The score was the number of correct items recalled in the correct position.

Raven. The Raven is a measure of abstract reasoning. The test consists of 36 items presented in ascending order of difficulty (i.e., easiest–hardest). Each item consists of a display of 3 × 3 matrices of geometric patterns with the bottom right pattern missing. The task for the participant is to select, among eight alternatives, the one that correctly completes the overall series of patterns. Participants had 10 minutes to complete the 18 odd-numbered items. A participant's score was the total number of correct solutions. Participants received two practice problems.

Verbal analogies. In this task participants read an incomplete analogy and were required to select the one word out of five possible words that best completed the analogy. After 1 practice item, participants had 5 minutes to complete 18 test items. A participant's score was the total number of items solved correctly.

Number series. In this task participants saw a series of number and were required to determine what the next number in the series should be. That is, the series follows some unstated rule, which participants are required to figure out in order to determine which the next number in the series should be. Participants selected their answer out of five possible numbers that were presented. Following 5 practice items, participants had 4.5 minutes to complete 15 test items. A participant's score was the total number of items solved correctly.

Free–free recall. In this task participants were given three lists of 10 words each. All words were common nouns, which were presented for 2 s each. After the presentation of the last word participants saw ???, which indicated that they should type as many words as they could remember from the current list in any order they wished. Participants had 50 s for recall. A participant's score was the proportion of items recalled correctly.

Cued–free recall. In this task participants were given three lists of 10 words each. All words were common nouns, which were presented for 2 s each. During the presentation of the word participants were also given a short cue phrase that was associated with the presented word. For instance, if the word was "moon", the cue phrase was "something that orbits". After the presentation of the last word participants saw ???, which indicated that they should type as many words as they could remember from the current list in any order they wished. Participants had 50 s for recall. A participant's score was the proportion of items recalled correctly.

Free–cued recall. In this task participants were given three lists of 10 words each. All words were common nouns, which were presented for 2 s each. After the presentation of the last word participants saw ??? and a cue phrase. Participants were instructed to type in the word from the current list that matched cue phrase. Cue phrases were randomly mixed so that the corresponding words were not recalled in the same order as they were presented. Participants had 5 s to type in the corresponding word. A participant's score was the proportion of items recalled correctly.

Cued–cued recall. In this task participants were given three lists of 10 words each. All words were common nouns, which were presented for 2 s each. During the presentation of the word participants were also given a short cue phrase that was associated with the presented word. After the presentation of the last word participants saw ??? and a cue phrase. Participants were instructed to type in the word from the current list that matched cue phrase. Cue phrases were randomly mixed so that the corresponding words were not recalled in the same order as they were presented. Participants had 5 s to type in the corresponding word. A participant's score was the proportion of items recalled correctly.

Results and discussion

First, recall accuracy in the four recall measures was examined to determine the effect of cues on recall performance. Shown in Table 1 are descriptive statistics for the four recall measures as well as overall accuracy levels. As can be seen, cues at both

Table 1. *Descriptive statistics and correlations for free and cued recall measures with latent composites of WMC and gF*

						Correlations	
Measure	*M*	*SD*	*Skew*	*Kurtosis*	*Rel*	*WMC*	*gF*
Overall accuracy	.64	.11	− 0.26	0.50	.74	.60	.46
Free−free	.65	.13	− 0.16	0.09	.56	.62	.59
Cued−free	.58	.14	0.60	0.79	.70	.53	.18
Free−cued	.60	.16	− 0.17	− 0.43	.69	.52	.36
Cued−cued	.72	.18	− 1.10	1.26	.77	.34	.22

Note: Correlations >.17 are significant at the $p < .05$ level; correlations >.22 are significant at the $p < .01$ level, and correlations >.28 are significant at $p < .001$. Rel = estimate of reliability. WMC = working-memory capacity. gF = general fluid intelligence.

encoding and retrieval significantly increased recall performance with the cued−cued measure demonstrating the highest accuracy. A repeated measures analysis of variance (ANOVA) with recall task as the within-subjects variable suggested a strong effect of task, $F(3,\ 408) = 42.24$, $MSE = 1.34$, $p < .01$, partial $\eta^2 = .24$. Follow-up contrasts suggested that performance on the cued−cued measure was significantly better than that on the other measures ($p < .01$), and the free−free measure was significantly better than either the cued−free or the free−cued measure (both ps < .01), while the last two measures did not differ significantly from one another ($p > .12$). Thus, consistent with Craik et al. (1987) it seems that cues only help performance when they are present at both encoding and retrieval similar to encoding specificity (Tulving & Thomson, 1973).

Next, a series of latent variable analyses were conducted to examine the extent to which the different recall measures would be related to cognitive ability measures. First, as shown in Table 1, each of the four recall measures was correlated with latent variables of WMC and gF. According to the SIP concept, tasks that require more SIP should correlate more highly with cognitive ability measures than tasks that require less SIP. Consistent with this, the free−free recall measure correlated the strongest with both WMC and gF, and the cued−cued tended to have the weakest correlations with WMC and gF. Specifically, the free−free measure had a significantly higher correlation with WMC (all ts > 2.33) and gF (all ts > 4.90) than did the other recall measures. Additionally, the cued−cued measure demonstrated significantly weaker correlations with WMC (all ts > 2.09) than did the other three recall measures, but the correlation with gF was only weaker than the free−free and free−cued measures (both ts > 2.10). Furthermore, the correlation between the free−free measure and WMC remained significant after partialling out the cued−cued measure, $pr(137) = .56$, $p < .001$, as did the correlation between the free−free measure and gF, $pr(137) = .56$, $p < .001$. The correlation between the cued−cued measure and WMC partialling out the free−free measure was not significantly different from zero, $pr(137) = .10$, $p > .24$, and neither was the correlation with gF, $pr(137) = -.05$, $p > .60$. Thus, consistent with previous theorizing, correlations between the recall measures and cognitive abilities was greatest when there was no support at either encoding or retrieval, and the correlations significantly decreased as the amount of support increased. Furthermore, tasks that theoretically required more SIP also accounted for a large amount of variance in cognitive abilities over and above that accounted for by tasks with less SIP.

To examine this further, a series of confirmatory factor analyses (CFA) were conducted in which the three WMC tasks formed a single latent variable, the three gF tasks formed a single latent variable, and two latent variables were constructed from the four recall tasks (i.e., free−free and cued–free formed one latent variable, and free–cued and cued–cued formed another).[1] In this way a latent variable was formed where there was no support at retrieval (free), and another latent variable was formed where there was support at retrieval (cued). As noted previously, situations where there is substantial support at retrieval should require less SIP leading to fewer systematic individual differences. As such the free latent variable should correlate more highly with both WMC and gF than the cued latent variable and should account for unique variance in both WMC and gF. The model is shown in Figure 2, and fit statistics are shown in Table 2. The fit of the model was acceptable ($p > .05$).

As can be seen, although the free and cued latent variables were related to one another, the free latent variable tended to correlate more highly with WMC and gF than did the cued latent variable. Indeed, the correlation between the free latent variable and WMC was significantly greater than the correlation between the cued latent variable and WMC, and the same was true for the correlation between the free latent variable and gF (both ts > 1.70, $p < .05$, one-tailed). In order to examine the shared and unique variance accounted for by both the free and cued latent variables, a structural equation model (SEM) was constructed to determine whether the free latent variable mediated the relation between the cued latent variable and WMC and gF. Shown in Figure 3 is the resulting model, and the fit indices are shown in Table 2. The fit of the model was generally acceptable despite a significant p-value ($p < .05$).

As can be seen, even though the free and cued latent variables were related to one another, the free latent variable accounted for unique variance

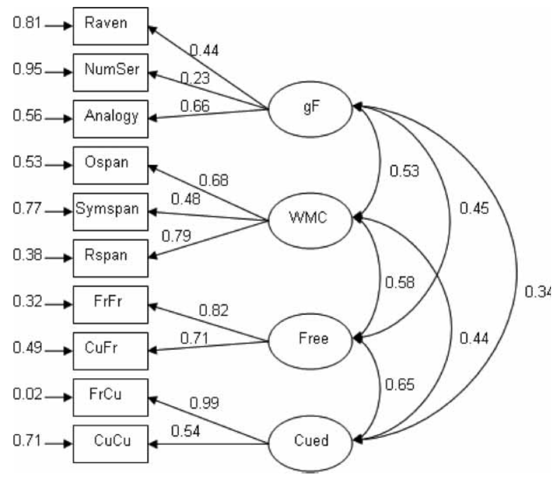

Figure 2. *Model for working-memory capacity (WMC), general fluid intelligence (gF), free recall measures (Free), and cued recall measures (Cued). Paths connecting latent variables (circles) to each other represent the correlations between the constructs, the numbers from the latent variables to the manifest variables (squares) represent the loadings of each task onto the latent variable, and numbers appearing next to each manifest variable represent error variance associated with each task. Raven = Raven advanced progressive matrices; NumSer = Thurstone's Number Series test; Analogy = paper and pencil verbal analogies test. Ospan = operation span task; Symspan = symmetry span task; Rspan = reading span task. FrFr = free–free recall; CuFr = cued–free recall; FrCu = free–cued recall; CuCu = cued–cued recall. Note all paths and loadings are significant at the p < .05 level.*

in both WMC and gF. The cued latent variable, however, was not significantly related to either WMC or gF after partialling out the shared variance with free latent variable. Thus, like the analyses conducted on each task alone, these analyses suggest that tasks that require more SIP correlate more highly with cognitive abilities than do tasks that require fewer SIP and account for significant unique variance in cognitive abilities.

[1] Note that prior to examining the CFA between the memory measures and WMC and gF, three separate memory models were examined to determine the separation of the free and cued measures. Specifically, Model 1 was similar to the model reported in Figure 2 with the free–free and cued–free measures forming a latent variable and the free–cued and cued–cued forming another latent variable to examine differences in retrieval. Model 2 examined differences in encoding with the free–free and free–cued forming one latent variable and the cued–free and cued–cued forming another latent variable. Finally, Model 3 represented the final combination of memory measures with the free–free and cued–cued forming one latent variable and the free–cued and cued–free forming another latent variable. Only Model 1, which was used in subsequent analyses, had an acceptable fit ($p > .11$; Model 2 and Model 3, ps $< .01$).

Table 2. *Fit indices for all models*

Model	χ^2	*df*	χ^2/df	*RMSEA*	*NFI*	*NNFI*	*CFI*	*SRMR*
Free/cued recall	42.42	29	1.46	.06	.91	.96	.97	.06
Free/cued recall SEM	45.70	30	1.52	.06	.90	.94	.96	.07
Higher order memory	6.60	11	0.60	.00	.98	1.00	1.00	.03
Higher order ability	44.70	31	1.44	.06	.91	.95	.97	.07

Note: RMSEA = root mean square error of approximation; NFI = normed fit index; NNFI = nonormed fit index; CFI = confirmatory fit index; SRMR = standardized root mean square residual. SEM = structural equation model.

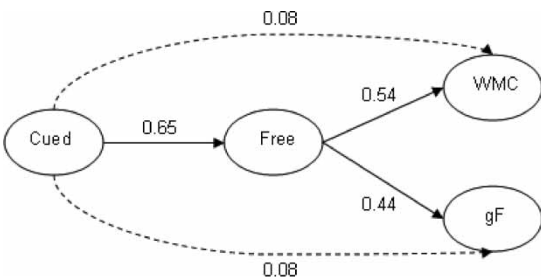

Figure 3. *Structural equation model examining unique and shared variance for the free and cued latent variables on working-memory capacity (WMC) and general fluid intelligence (gF). FrFr = free–free recall; CuFr = cued–free recall; FrCu = free–cued recall; CuCu = cued–cued recall. Note that solid paths are significant at the p < .05 level, while dotted paths are not significant.*

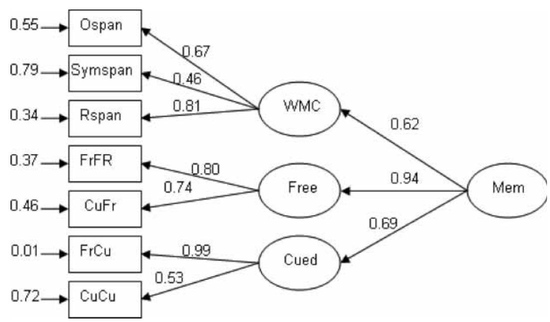

Figure 4. *Model for higher order memory factor (Mem) based on first-order factors composted working-memory capacity (WMC), free recall (Free), and cued recall (Cued). Ospan = operation span task; Symspan = symmetry span task; Rspan = reading span task. Note that all paths and loadings are significant at the p < .05 level.*

The final two latent variable analyses examined the extent to which the various memory measures would be related to one another, and this common variance would be related to gF. Specifically, as noted previously, even though it has been argued that the correlation between performance on memory tasks and cognitive abilities should change as a function of the amount of SIP that is required, tasks that require fewer SIP still correlate with tasks that require more SIP and with cognitive abilities. In order to examine this a higher order CFA was conducted in which the variance common to the WMC, free, and cued latent variables was extracted. In this model, the three memory latent variables were treated as first-order factors, and a higher order memory (Mem) factor was formed based on the variance common to the three lower order factors. Note WMC was included in this model because WMC measures should require a large amount of SIP given that there is generally no support at encoding or retrieval. The resulting higher order model is shown in Figure 4, and the fit indices are shown in Table 2. The fit of the model was acceptable ($p > .83$).

As can be seen, the three lower order factors all significantly load on the higher order factor, suggesting that they all share a good deal of common variance. Next, this model was combined with the gF latent variable to see how the common memory variance would be related to gF. The model is shown in Figure 5, and fit indices are shown in Table 2. The overall fit of the model was acceptable ($p > .05$). As shown in Figure 5, the variance common to all of the memory measures was significantly related to gF. These analyses demonstrated that although the correlations between performance on a memory task

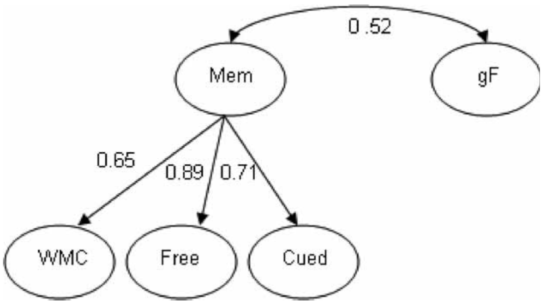

Figure 5. *Model examining relation between the higher order memory (Mem) factor and general fluid intelligence (gF). The path connecting the latent variables (circles) to each other represents the correlation between the constructs. Note that all paths and loadings are significant at the p < .05 level.*

and cognitive abilities changes as a function of the amount of SIP required, there is still a substantial amount of shared variance across memory tasks (which reflects the amount of shared processes), and this shared variance is related to gF. Thus, there are both unique and shared sources of variance across the memory tasks, both of which are related to cognitive abilities.

Conclusion

Overall these results suggest that Craik's (1983, 1986) view of SIP, which has been used to account for age differences on memory tasks, can be applied to individual differences within an age group as well. In particular the results suggest that the discrimination power of a task is determined in part by the amount of SIP that is likely to be required on the task. Furthermore, the results suggest that these SIP can be thought of as different component control processes, which are required on some tasks more than others. In particular, tasks like free recall require many SIP because these tasks require participants to organize information at encoding as well as to set up cues at retrieval and monitor the products of a controlled search of memory. Tasks like cued recall require less SIP, and hence fewer component control processes, because environmental support is available at retrieval. Evidence consistent with this is the finding that free recall tasks account for variance over and above what is accounted for by cued recall tasks. Theoretically, this unique variance represents those processes engaged in the free recall task that are not utilized in the cued recall task, such as forming greater interitem associations at encoding, the setting up of multiple cues at retrieval, and utilizing multiple recursive search strategies. Furthermore, the shared variance between the two tasks represents those component processes that are utilized by both tasks, such as utilizing cues at retrieval, reinstating the encoding context at retrieval, and monitoring the products of retrieval. Thus, the results of the current study suggest that the notion of SIP is important for determining the predictive power of a task (or the extent it correlates with other cognitive abilities), and SIP can be thought of as various component control processes, which will be needed in different forms on different tasks. As such the current study provides an important first step in examining these notions and demonstrating that the discrimination power of a task varies in meaningful ways, which has important implications for examining individual and group differences, as well as neuropsychological differences.

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