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## Episodic memory and organizational strategy in free recall in unipolar depression: The role of cognitive support and executive functions

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Executive functioning and memory impairment have been demonstrated in adults with depression. Executive functions and memory are related, mainly when the memory tasks require controlled processes (attentional resource demanding processes)—that is, when a low cognitive support (external aid) is provided. A cross-sectional study was carried out on 45 participants: 21 with depression, and 24 healthy controls matched for age, verbal ability, education level, and anxiety score. Cognitive support was manipulated by providing a categorized word list at encoding, presented either clustered (high cognitive support) or randomized (low cognitive support) to both depressed and healthy adults. The number of words recalled was calculated, and an index of clustering was computed to assess organizational strategies. Participants were also administered cognitive tests (executive functions, cognitive speed, and categorical fluency) to explore the mediators of organizational strategies. Depressed participants had greater difficulty recalling and organizing the words, but the differences between the two groups were reduced for both measures when high cognitive support was provided at encoding. Healthy adults performed better on all cognitive tests. Statistical analyses revealed that in the depressed group, executive functions were the only variable associated with clustering and only when low cognitive support was provided. These findings support the view that the decrement in executive function due to depression may lead to impairment in organization when this mnemonic strategy has to be self-initiated.

**Keywords:** Depression; Organizational strategies; Free recall; Episodic memory; Executive functions; Cognitive support.

### INTRODUCTION

Impairment in episodic memory is common in major depressive disorders (MDD; e.g., Fossati, Amar, Raoux, Ergis, & Allilaire, 1999; Fossati, Coyette, Ergis, & Allilaire, 2002; Fossati et al., 2004; Golinkoff & Sweeney, 1989; Ilsey, Moffoot, & O'Carroll, 1995; and see Burt, Zembar, & Niederehe, 1995; Veiel, 1997, for reviews). However, Hartlage, Alloy, Vázquez, and Dykman (1993) showed that the degree of impairment seems to depend on the type of task used to evaluate episodic memory, and that depressed patients evidence more important declines when the task requires greater engagement of self-initiated, controlled processes (i.e., processes requiring attentional resources, Schneider & Shiffrin, 1977). Convergent results have been reported in studies comparing explicit and implicit memory tasks (e.g., Danion, Willard-Schroeder,

Zimmermann, & Grangé, 1991), controlled and automatic processes (Hertel & Milan, 1994; Jermann, Van der Linden, Adam, Ceschi, & Perroud, 2005), recall and recognition (Calev & Erwin, 1985), or recollection and familiarity judgments (Lemogne et al., 2006). Hence, a deficit in controlled processes could account for depression-related memory impairment.

Fossati et al. (2002) also suggested that memory deficits in depression might stem from the impairment of executive functions, as the depressed patients in their study who had the poorest executive functions also had the lowest memory scores. They therefore proposed an “executive memory decline hypothesis in depression.” Although not a unitary construct (Miyake et al., 2000), executive functions refer to a set of cognitive processes that are involved in the conscious, controlled, and strategic aspects of cognition. In memory, the influence of executive functions is notable at both encoding and retrieval (Buckner, 2003; Moscovitch & Winocur, 1992; Shimamura, 2002). Suboptimal executive functions observed in depressed patients (Fossati et al., 2002; Merriam, Thase, Haas, Keshavan, & Sweeney, 1999) may thus negatively affect the strategic aspects of memory. Because executive functions are necessary for implementing strategic and controlled processes, both the control process deficit hypothesis and the dysexecutive hypothesis could explain the memory decline associated with depression.

Cognitive support—that is, external context that supports the mental operations required at the encoding and retrieval stages of episodic memory (Craig & Jacoby, 1996)—allows alleviation of the deficit in mnemonic performance of people with low executive functions when provided at encoding (Bunce, 2003) or retrieval (Taconnat, Clarys, Vanneste, Bouazzaoui, & Isingrini, 2007), thereby reducing the demand on self-initiated, controlled processes. In an earlier study, Bäckman and Forsell (1994) manipulated the cognitive support at encoding by presenting elderly healthy and depressed adults with either organizable (i.e., the words belong to particular semantic categories and can be clustered, which helps memory and, thus, corresponds to a high cognitive support) or non-organizable lists (i.e., each word belong to a different semantic category and cannot be clustered, which corresponds to a low cognitive support). The authors measured memory performances with a free-recall, cued recall, or recognition task. Their results showed that healthy elderly adults performed better than their depressed counterparts. However, recognition produced smaller group differences than recall, implying that the deficit could be reduced by providing additional support at retrieval. In contrast, in the recall test, the depressed patients did not benefit as much as healthy adults from extra support at encoding (organizable lists), suggesting that they did not use the organizational strategy to improve their memory performances. Channon, Baker, and Robertson (1993) made a similar finding among younger healthy and depressed people, which they interpreted as a failure of the latter to initiate encoding strategies.

Organizational strategy can be considered as one of the most efficient means of improving free recall in the absence of cognitive support (i.e., cue). Experimental studies on clustering and recall quantify these strategies by computing indices of clustering associated with semantic (e.g., Adjusted Ratio Clustering, ARC, Roenker, Thompson, & Brown, 1971) or subjective organization (e.g., Pair Frequency, PF, Tulving, 1962). Semantic organization refers to the degree to which participants group semantically related words (categories, instances, associates, synonyms) during recall. Subjective organization is shown when participants recall unrelated words in the same order in successive trials. The ability to cluster information as a mnemonic strategy is sometimes impaired in older (Bäckman & Forsell, 1994) and young

depressed adults (Calev & Erwin, 1985; Russell & Beekhuis, 1976; Weingartner, 1981), in patients with frontal lobe lesions (e.g., Gershberg & Shimamura, 1995), and in healthy elderly adults (e.g., Tacconnat et al., 2009; West & Thorn, 2001). All these studies involve groups who have some degree of executive impairment, and the memory task showing the greatest effect is free recall, which depends on strategies supported by executive functions (Moscovitch & Winocur, 1992). Thus, the deficits in memory and organizational strategies observed in these groups may reflect impairment in executive control (see Gershberg & Shimamura, 1995; Stuss et al., 1994, for discussion of this point). Consequently, it is plausible to assume that the decline in free recall and organizational strategy related to depression might be associated with impairment in executive functioning.

The present study focuses on the impact of MDD on episodic memory and categorical clustering during a free-recall test and on the possibility of improving memory and clustering performance by providing extra cognitive support at encoding in young depressed adults. Although the mnemonic decline associated with depression is well known, few studies have manipulated experimental variables affecting performance in episodic memory tasks in depressed people. Moreover, the involvement of executive dysfunction and the subsequent poor use of organizational strategies have been explored in patients with frontal lobe lesions and healthy elderly adults but not in depressive patients. These manipulations would enable the cognitive processes underlying memory functioning in depression to be better understood. Performance in free recall depends on the organizational strategy used (Bäckman & Forsell, 1994; Denney, 1974; Tacconnat et al., 2009), and when a categorizable list is presented randomly, the participants have to actively organize the items during recall (i.e., a self-initiated process), a strategy that might in turn rely on executive functioning. By contrast, when the category items are presented in a blocked fashion (i.e., clustered), and the organizational strategy is implemented passively, the association between successful recall and better executive functioning should be weaker. We therefore predicted that depressed participants would recall more words when presented with a clustered than with a randomized list.

Although we expected that depressed participants would not recall and organize items as well as the healthy participants, we predicted that the differences would be reduced when high cognitive support was provided at encoding. Moreover, if organization is used as a strategy to enhance recall, the clustering index (ARC, Roenker et al., 1971) should be positively and significantly correlated with the recall score in the healthy group (Denney, 1974; Tacconnat et al., 2009). By contrast, because depressed adults may have difficulty implementing the best mnemonic strategies, we assumed that the clustering index would show a weaker association with the recall score in depressed adults.

Finally, this study was designed to investigate further the role of executive functions in implementing an organizational strategy during free recall and specifically in depression. We expected that when organization is active and thus relies on controlled processes, the clustering index would be closely related to that of executive functioning in both groups. However, we expected this association to be weaker when the clustering index was calculated from the recall of a blocked list—that is, passive clustering. Moreover, because depression is also associated with a significant decline in processing speed, irrespective of executive deficits (Tsourtos, Thompson, & Stough, 2002), and in categorical fluency (Fossati et al., 1999), which could be related to categorical clustering, we tested the specificity of the executive functioning hypothesis by comparing its effects with those of cognitive speed and categorical fluency.

## **METHOD**

### **Participants**

A total of 45 French adults living in a medium-sized metropolitan area took part in the study. They were divided into two groups: “healthy” ( $n = 24$ , age 20–40 years, 16 women) and “depressed” ( $n = 21$ , age 20–40 years, 15 women). The two groups were matched for the number of years of formal education and their verbal ability, assessed with the Mill Hill vocabulary test (Raven, Court, & Raven, 1986). The self-reported health score was measured on a 5-point scale from 0 (poor health) to 5 (good health). Anxiety and depression scores were measured on the Hospital Anxiety and Depression Scale (HADS, Zigmond & Snaith, 1983) for both groups. All participants from the depressed group were in-patients at the Tours teaching hospital and met the criteria for major unipolar depression. They were interviewed by experienced psychiatrists and diagnoses of depression were made by using DSM-IV (Diagnostic and Statistical Manual of Mental Disorders—Fourth Edition) criteria (American Psychiatric Association, 1994). Participants with psychotic features, with a history of alcoholism or use of other psychoactive substances, who were undergoing treatment for psychiatric illness, or who had received benzodiazepines or antidepressant medication for more than two weeks before testing were excluded from the study. Ethical approval for the research was obtained from the Psychology Department of Tours University. Control participants were recruited from people who were associated with the depressed group. They were also interviewed and were excluded if there was any evidence of psychiatric history, neurological history, psychoactive substance abuse, or use of medication that might potentially influence cognition. All participants were volunteers and gave their signed consent. At the end of the experiment, participants were informed about the general goal of the research. The characteristics of each group are presented in Table 1. No significant difference was observed between the two groups for age, level of education, or vocabulary level, but there was a significant difference in self-reported health.

### **Materials and procedure**

Cognitive support was manipulated by presenting two kinds of list to the same participant. One list was clustered—that is, words belonging to the same category were presented in blocks—and the other was categorizable, with words from different categories presented at random. This enabled the different types of organization to be studied, one benefiting from the presentation format (high cognitive support, clustered list, blocked presentation) and the other requiring self-initiation (low cognitive support, organizable list, random presentation). Two sessions were thus required for the experiment; in the first, participants were screened for the inclusion criteria, were assessed with the Mill Hill vocabulary test, and performed one of the experimental episodic memory tasks. In the second session, they performed the second experimental episodic memory task and completed the battery of cognitive tests. The two lists were counterbalanced at each session to avoid any order effect on recall and clustering. In each session, participants carried out the processing speed task, which served as an interfering task between learning and recall. However, only the results of the first session were analyzed to assess processing speed to avoid a learning bias in the second session.

**TABLE 1.** Characteristics of participants by group.

	Healthy (n = 24)	Depressed (n = 21)	t (43)
Age (in years)	28.45 (4.55)	29.7 (5.5)	0.83
Mill Hill vocabulary test	21.66 (3.13)	20.4 (4.6)	0.85
Years of formal education	11.92 (1.71)	12.5 (2.4)	0.93
Self-reported health score	3.87 (.67)	2.6 (1.0)	5.06***
HADS, Anxiety score	6.79 (3.68)	8.0 (2.8)	1.22
HADS, Depression score	7.1 (3.32)	11.8 (3.4)	3.64**

*Note.* HADS: Hospital Anxiety and Depression Scale. Means; standard deviations in parentheses. \*\* $p < .01$ . \*\*\* $p < .001$ .

### **Experimental tasks: Episodic memory and clustering**

Participants were shown two (one per session) categorized 20-word lists (5 categories of 4 words). In one list, the words were arranged and presented in pseudorandom order so that two words from the same category were never shown sequentially (random condition). Participants were not aware before beginning the task of the possible structuring of the list, but were informed about the subsequent memory test. In the second list, the words were presented in blocks, each corresponding to an unnamed semantic category item (blocked condition). The word categories were counterbalanced from one condition to the other so that the words were presented in both the random and blocked conditions, but participants only learned the words in one condition (random or blocked). Altogether there were thus 10 categories of 4 words. The words from these categories were taken from Marchal and Nicolas's table (2003). They were matched for word length, frequency (Brulex database, Content, Mousty, & Radeau, 1990), and semantic category typicality. All the words were concrete nouns composed of 5–7 letters with 2–3 syllables. They were shown on a computer screen for 3 s each, with an interstimulus interval of 500 ms. After presentation of the whole list, participants performed a letter comparison task (X–O) for 45 s. This task served both as an interference task to prevent the recency effect and as a measure of processing speed. After the X–O task, the participants were asked to recall and say aloud as many words as possible, which were written down by the experimenter to avoid any effect of writing difficulty. At the end of learning and recall, participants rested for a few minutes before carrying out the remaining tests.

The ARC score developed by Roenker et al. (1971) was used as a measure of categorical organization at recall. The ARC score assumes chance clustering to be 0 and perfect clustering to be 1 and is computed according to the following formula:  $ARC = [R - E(R)] / [\max R - E(R)]$ , where R is the total number of category repetitions, maxR is the maximum possible number of category repetitions, and E(R) is the expected (chance) number of category repetitions (Roenker et al., 1971, p. 46). It adjusts for the differences in the total number of items recalled, which is important considering that healthy adults may recall more words than depressed patients. Thus, ARC scores are relatively independent of the recall score, inasmuch as a low recall score may lead to a high ARC score if the words are recalled in an organized manner.

### **Cognitive assessment**

Three cognitive tests were selected, designed specifically to evaluate different cognitive functions such as executive functions, speed, and categorical fluency (one score for each function). These cognitive abilities were selected because they are known to be related to depression and might be associated with the dependent

variables studied here. The association of each variable with clustering and recall was examined to identify those that were most closely associated.

### ***Executive functions***

To assess executive functioning, we used the Wisconsin Card Sorting Test (WCST), which is sensitive to frontal lobe lesions and is thought to be a valid measure of executive functions (Lezak, 1995; Miyake et al., 2000; Spreen & Strauss, 1998). It was administered and scored following the standard procedure using two packs of 64 cards (Heaton, Chelune, Talley, Kay, & Curtiss, 1993; Lezak, 1995). The specific measure retained here was the number of perseverative errors, which is closely associated with general executive functioning (Miyake et al., 2000). Perseveration reflects difficulty in discontinuing a prepotent response or use of a previously reinforced strategy that is no longer relevant. The number of perseverative errors thus seems to be an appropriate measure of the ability to use the best strategy to learn a categorized word list, where clustering is required to improve mnemonic performance. A high score on this test reflects low executive functioning, and this test is sensitive to depression (Fossati et al., 1999).

### ***Processing speed***

The test used to assess processing speed was the letter comparison test (Salthouse, 1990), in which participants were presented with a page containing pairs of letters (X–O). They were instructed to decide as fast as possible whether the two members of the pair were identical or not and to tick the “identical” or “different” column accordingly. The dependent measure was the number of items answered correctly within 45 seconds. The measure retained here was the number of pairs completed correctly in the first session, to avoid any learning effect.

### ***Categorical fluency test***

The categorical fluency test (from the Controlled Oral Word Association Test; Benton, Hamsher, & Sivan, 1983) was used to assess organization in semantic memory. In this test, participants were required to articulate, within a 60-s time constraint, as many different words as possible within a certain category (here: animals, fruit, vegetables). This test is sensitive to depression (Fossati et al., 1999) and has also been found to be sensitive to the level of functional activity in the frontal cortex (Frith, Friston, Liddle, & Frackowiak, 1991; Gourovitch, Kirkby, & Goldberg, 2000). However, it has also been shown to be associated with temporal lobe activity (Pihlajamäki et al., 2000), and it was therefore analyzed separately from the WCST, which is an executive task more definitively (although not exclusively) associated with the frontal brain regions. This measure was intended to gauge the dependence of clustering strategy use on semantic and episodic organization ability. The participants' score retained here was the total number of correct words generated across all three trials divided by three.

## **RESULTS**

### **Depression, cognitive support, and clustering**

Examination of the distribution of ARC scores revealed a clear departure from normality. Some participants attained very high scores indicating consistent use of clustering, while others showed limited use of that strategy. Thus, ARC scores were not amenable to the parametric statistical analysis. Because of the irregular pattern of this distribution, clustering use was categorized as a dichotomous “yes–no” variable,

with “yes” corresponding to ARC scores above .9, and “no” below that score. Each group was divided into two subgroups accordingly, corresponding to the clustering use level, a variable used in the analysis of variance (ANOVA) performed in the next section of the results.

The proportion of people using clustering at the .9–1.0 level (near or at the maximum level) differed significantly between groups. In the blocked list, 65.15% of the control participants and 54.17% of the depressed participants used clustering at the maximum level,  $\chi^2(1) = 0.69$ , ns. However, in the random list, 66.82% of the control participants used clustering at the maximum level, compared to only 37.50% of the depressed participants,  $\chi^2(1) = 3.91$ ,  $p < .05$ .

### **Effects of depression, clustering use, and cognitive support on recall**

The descriptive statistics of performance in recall and clustering index are presented in Table 2.

To examine the effects of use of clustering, cognitive support, and depression on free recall, we conducted a 2 (group)  $\times$  2 (cognitive support)  $\times$  2 (clustering use) mixed ANOVA on the recall scores. The results are shown in Figure 1.

This analysis showed a main effect of group,  $F(1, 41) = 150.25$ ,  $p < .0001$ , indicating that healthy adults recalled more words than the depressed patients, a main effect of cognitive support,  $F(1, 41) = 78.02$ ,  $p < .0001$ , indicating that the words were recalled better when they were presented in a block than at random, and a main effect of clustering use,  $F(1, 41) = 5.43$ ,  $p < .05$ , indicating that the participants who used this strategy recalled more words. The significant interaction between the three variables,  $F(1, 41) = 5.55$ ,  $p < .05$ , showed that the effect of clustering use was different according to the group of participants and the level of cognitive support. Simple interactions allow this result to be specified. The interaction between group and cognitive support was significant,  $F(1, 41) = 8.14$ ,  $p < .01$ , showing that the effect of cognitive support was different for the depressed patients and the healthy participants. Further analyses showed that cognitive support helped only the depressed group to recall better,  $t(21) = 8.71$ ,  $p < .001$ , with no effect on the recall performance of the healthy group,  $t(24) = 0.79$ , ns. The interaction between clustering use and group was significant,  $F(1, 41) = 5.44$ ,  $p < .05$ , and indicated that the use of the clustering strategy did not benefit the two groups in the same way; clustering use helped only the healthy participants,  $t(22) = 3.08$ ,  $p < .01$ , for the healthy group and  $t(19) = 0.27$ , ns, for the depressed group. Finally, the interaction between cognitive support and clustering use was significant,  $F(1, 41) = 12.07$ ,  $p < .01$ , indicating that the use of clustering did not affect the recall of the random list and the recall of blocked list in the same way; the clustering use increases the recall of words randomly presented,  $t(43) = 4.19$ ,  $p < .01$ , but not that of the words presented in blocks,  $t(43) = 1.25$ , ns.

**TABLE 2.** Means of proportion of recall as a function of group and type of list.

	Healthy (n = 24)	Depressive (n = 21)
<b>Recall</b>		
Blocked	13.62 (2.16)	10.57 (1.24)
Random	13.08 (2.46)	7.14 (1.31)
<b>ARC</b>		
Blocked	.81 (.16)	.83 (.23)
Random	.76 (.27)	.51 (.35)

*Note.* Type of list: blocked vs. random; standard deviations in parentheses. ARC = Adjusted Ratio Clustering.



### Cognitive measures

The descriptive statistics for these measures are presented in Table 3. In agreement with the literature, the comparisons presented in this table show that healthy participants performed better on all measures, especially with regard to the number of perseverative errors ( $p < .0001$ ).

**TABLE 3.** Means of cognitive measures as a function of group;

	Healthy (n = 24)	Depressed (n = 21)	t (43)
<b>WCST-PE</b>	10.33 (3.78)	29.9 (9.8)	9.94***
<b>Speed</b>	34.8 (7.03)	30.1 (5.5)	2.38**
<b>Fluency</b>	50.08 (9.39)	43.5 (8.0)	2.36**

*Note.* WCST-PE: Number of perseverative errors on the Wisconsin Card Sorting Test, the measure of executive functions. Speed: Number of pairs completed in the letter comparison test. Fluency: Number of words generated in the Categorical Fluency test. Standard deviations in parentheses. \*\* $p < .01$ . \*\*\* $p < .001$ .

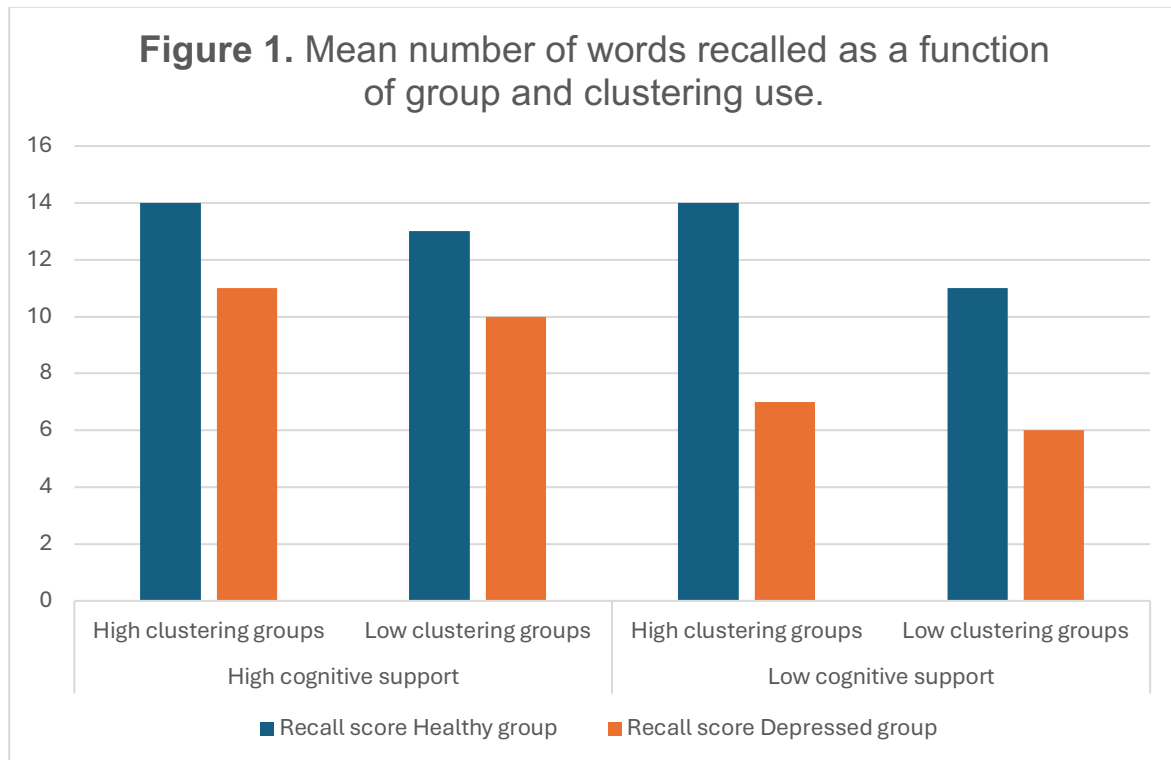
### Association between recall, clustering use, and cognitive measures

Associations between all the variables were assessed using the nonparametric Spearman correlation coefficient  $r$ . The analyses were conducted separately for the control and depressed groups because the profiles of results differed between the two groups (i.e., for recall, there were significant interactions between group and clustering use, and between cognitive support and group). The results are presented in Table 4. A Bonferroni correction for multiple comparisons was applied, the results without the correction are presented in the tables, and notes specify which correlations remained significant after this correction. Only the correlations that remained significant are discussed.

Based on studies showing that the use of encoding strategies relies on executive functions, we assumed that the organization would be specifically correlated with the number of perseverative errors on the WCST in the random condition only. Better recall was expected to be associated with higher clustering scores, on the assumption that organization is an encoding strategy that assists recall. However, as shown by the previous analysis, recall and clustering should be correlated only among the healthy adults. On the other hand, free recall, already shown to depend on executive functions (e.g., Parkin, Yeomans, & Bindschaedler, 1994) was expected to show significant links with the number of perseverative errors on the WCST and processing speed.

As expected, recall of the random list correlated positively with the clustering index only in the healthy group ( $r = .86$ , see Table 4). This result indicates that, only in the healthy group, the more the participants used the clustering strategy, the more items they recalled. This finding corroborates the ANOVA results, which showed that the use of clustering as a recall strategy was only beneficial for the participants of the healthy group.

As expected, ARC scores for the random list were correlated with the number of perseverative errors on the WCST (measure of executive function;  $r = -.53$ , and  $r = -.85$ , for the healthy and depressed groups, respectively); however, with the Bonferroni correction for multiple comparisons, this association remained significant only for the depressed group. Thus, use of an "active" clustering strategy was associated with greater executive functioning.



## DISCUSSION

Memory performance and capacity to organize materials has been examined with preorganized (high cognitive support) and nonorganized word lists (low cognitive support) in depressed patients and control participants. On the one hand the main results showed that memory deficits due to depression only occurred when the patients had to organize the information themselves—that is, in the low cognitive support condition. On the other hand, they showed that they were less able to use an organizational strategy, as measured by the ARC score. This poor organizational capacity reveals deficits in controlled, self-initiated processing. As expected, these deficits were associated with poor executive function performance. These findings are in line with the “executive memory decline hypothesis in depression” proposed by Fossati et al. (2002) and with depression related modification in cerebral regions associated to executive functions (e.g., Hugdahl et al., 2007; Menon, Anagnoson, Mathalon, Glover, & Pfefferbaum, 2001).

They are also congruent with the view that executive functions are involved in strategic components of memory (Moscovitch & Winocur, 1992). Although depressed patients performed poorly when the task called for the spontaneous generation of organizational strategy, they benefited more from high external cognitive support (i.e., blocked presentation) than the healthy participants (see Channon et al., 1993, for similar results). It can be argued that the recall task relies less on controlled processes in the blocked than in the random presentation condition. Thus, our results are in agreement with those of studies indicating that the memory impairment of depressed patients depends on the type of task and that their impairment appears mainly in memory tasks that require controlled, and thus self-initiated, processes (e.g., Fossati et al., 2002; Jermann et al., 2005). In the healthy group, providing or not cognitive support (blocked vs. random list) had no effect on the recall score, suggesting that healthy participants implement self-initiated processes that allow them to perform as

well with the random list (low cognitive support) as with the blocked list (high cognitive support).

**TABLE 4.** Correlation matrix between cognitive measures and dependent variables;

Group	N		Recall		ARC		WCST-PE	Speed
			Blocked list	Random list	Blocked list	Random list		
Healthy <sup>a</sup>	24	Recall random list	.19					
		ARC blocked list	.20	.23				
		ARC random list	.20	.86***	.26	.26		
		WCST-PE	-.21	-.48**	-.18	-.53**		
		Speed	.15	.28	.41*	.23	.02	
		Fluency	.11	.09	.21	.02	-.32+	.12
Depressive <sup>b</sup>	24	Recall random list	.14					
		ARC blocked list	.47*	.37				
		ARC random list	.37	.21	.16			
		WCST-PE	.19	-.48**	.35	-.85***		
		Speed	-.38	.30	.50**	.32	-.17	
		Fluency	.43*	.32	.34	.17	-.34	.42*

Note. ARC = Adjusted Ratio Clustering. WCST-PE: Number of perseverative errors on the Wisconsin Card Sorting Test, the measure of executive functions.

<sup>a</sup>For the healthy group, only the correlation between the ARC obtained for the random list and the performance in recall of that list (.86) remained significant after the Bonferroni correction for multiple comparisons. <sup>b</sup>For the depressive group, only the correlation between the ARC obtained for the random list and the number of perseverative errors to the WCST (-.85) remained significant after the Bonferroni correction for multiple comparisons. + $p < .1$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ , without Bonferroni correction.

On the same lines, the pattern of results obtained for the clustering strategy use shows that depressed adults were less likely to use an active clustering strategy than were healthy participants, replicating findings of earlier research (Calev & Erwin, 1985; Channon et al., 1993; Russell & Beekhuis, 1976; Weingartner, 1981). However, when the words were presented by category (blocked list), there was no difference between the two groups on the clustering index. In this situation, clustering is not an active strategy that has to be implemented to enhance recall, but corresponds to the recall of words in their order of presentation. This finding implies that both memory and clustering deficits observed in people suffering from depression can be alleviated by providing support at encoding.

The clustering index computed from the recall score for the random list was correlated with the recall performance of the healthy group, indicating that the more the words were organized at recall, the better the recall performance (see Denney, 1974; Taconnat et al., 2009, for similar results). This was not the case for the depressed group. Bäckman and Forsell (1994) found a similar result with elderly depressed adults, where clustering and recall were not associated. This result may thus be extended to young depressed adults and indicates that the patients who organize better information are not necessarily those who recall the most words. This lack of correlation between organization strategy use and recall score might be interpreted by the fact that both organization and recall require attentional resources and that the frontal cortex, which is implicated not only in executive function but also in attentional control (e.g., Blasi et al., 2006), is impaired in depressed patients. Thus, given their poor attentional

resources, it is possible that they allocate their attention either to clustering or to recall, but perhaps not to both. That would be conducive to poor recall when clustering is close to that of healthy participants and, conversely, to poor clustering when recall is close to that of healthy participants. This interpretation necessitates future research to be corroborated. This interpretation in terms of a deficit in strategy implementation is in agreement with Channon et al.'s (1993) conclusions. However, in their study, these authors did not compute a strategy index, but only the recall scores of word lists differing in their structure (i.e., clustered categorized list, randomized list, and uncategorized list). The present study, where the organizational strategy was qualified by the ARC score, showed more directly that the depressed patients suffered from a deficit in self-initiating a clustering strategy.

The results of this study also support the view that a deficit in executive functions, measured with the number of perseverative errors to the WCST, underlies the poor performance of depressed patients on memory tests, especially those that rely heavily on controlled processes. Indeed, among the three cognitive variables that we investigated (i.e., processing speed, categorical fluency and executive function), executive function was the only one correlated with the active clustering strategy index (random list) in both groups, although this correlation became nonsignificant in the healthy group after the Bonferroni correction. This smaller correlation in the healthy group might be due to a lack of variance in the number of perseverative errors made by these participants. This result underpins the executive memory decline hypothesis in depression. Examination of characteristics of the two subgroups of depressed participants reinforces that conclusion, showing that only the number of perseverative errors to the WCST allows differentiation of the two subgroups (mean of 23 errors for the high clustering group, mean of 34.78 errors for the low clustering group,  $t = 3.41$ ,  $p < .01$ ). However, one of the limitations of this study is its reliance on a single index of executive functioning: the number of perseverative errors on the WCST. Although this index seems simple, it is a complex measure that depends on response to feedback and inhibition of prepotent responses (Gohier et al., 2008). This measure is closely associated with general executive functioning (Miyake et al., 2000). It is also representative of cognitive flexibility (Kaplan, Sengör, Gürvit, Genç, & Güzelis, 2006), which is a function involved in the use of adaptive strategies (e.g., Ridderinkhof, Span, & van der Molen, 2002). The role of cognitive flexibility in the recall of a categorized word list might be to prevent recalling the learned words in the order of presentation and to reorganize them on the basis of their semantic category, so that words of the same category are recalled together (clustering). In this case, the category name would serve as a retrieval cue, explaining why clustering helps recall. Thus, decline in cognitive flexibility due to depression (Fossati, Le Bastard, Ergis, & Allilaire, 2003) could explain the impaired use of organizational strategies.

In sum, on the basis of the findings presented here, we conclude that although clustering is a beneficial strategy for enhancing recall of verbal material, its benefits depend on an effortful process, the implementation of a self-initiated strategy, which depressed people lack. However, when clustering strategy is cued externally and is made more automatic and less dependent on executive control, the deficits are significantly reduced. This indicates that depression-related memory impairment relies at least partially on difficulty in self-initiating relevant cognitive processes in order to perform memory tasks better. Therefore, improving executive functions and providing alternative strategies are potentially of value for training programs aimed at reducing memory deficits in depression.

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