Serial position effects scoring in the assessment of memory in Alzheimer's disease and major depression

Bemelmans, K.J.

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Evidence for two processes underlying the serial position curve of single- & multi-trial free recall in a heterogeneous group of psychiatric patients: A confirmatory factor analytic study

Karel J.Bemelmans, MSc[1]
Gezinus Wolters, PhD [2]
Koos Zwinderman, PhD[3]
Jos M.F. ten Berge, PhD[4]
Jaap G. Goekoop, MD, PhD[5]

(1) From the [1]Division of Medical and Biological Research, Rijngeest Group, [2]Department of Psychology, [3]Department of Medical Statistics, Leiden University, [4]Heijmans Institute, Groningen University, [5]Department of Psychiatry, Leiden University Medical Centre, The Netherlands

Memory 2002, 10, 151-160

Abstract

The 'U'-shaped serial position curve (SPC) of single-trial free recall is a well-established empirical fact, and there is ample evidence that it is the result of two different memory functions. However, it is insufficiently clear whether the same holds true for the SPC of multi-trial free-recall. Free recall test measurements of two large heterogeneous groups of psychiatric patients were subjected to factor extraction using Principal Components Analysis and oblique rotation in two studies. The results of these two experiments show that the SPC of single & multi-trial free recall underlie the same two functions i.e. one function underlies the recency part, the other the primacy and middle (prerecency) part. Possible theoretical interpretations are discussed.

Introduction

The 'U'-shaped serial position curve (SPC) of single-trial free recall is a well-established empirical fact. It is attained by plotting the frequency of recall of an item against the position of that item in a list. Typically the last few items are more frequently recalled than items at the beginning and the least frequently recalled items are in the middle. The higher frequencies of the last and the first items are ascribed to recency and primacy effects.

Because the primacy and recency effects can be differentially altered by manipulating variables such as list length, and rehearsal or by the use of distractor tasks such as subsequent arithmetic task before recall or delayed recall [2,15,38], different memory functions have been hypothesized. One hypothesis has been that the recency part of the SPC is associated with short-term store (STS) and the primacy and middle (prerecency) part is associated with long-term store (LTS) [15]. This has been called the modal model. According to Atkinson & Shiffrin [1], who devoted considerable attention to performance in the standard single-trial free-recall task, each stimulus enters a fixed-capacity rehearsal buffer and displaces a randomly selected item already there when the capacity (about four items) is exceeded. As long as an item is in the buffer, information about it is transferred to a permanent LTS. The amount of information transferred is a linear function of the time in the buffer. At the time of test, subjects initially output the items still remaining in the buffer and then make a fixed number of searches of LTS. However, crucial to the modal model are the assumptions that an item may be retained in the STS buffer as well as the LTS at the same time and that recall of any particular item, including those presented most recently, can derive from information in both STS and LTS. The U-shaped SPC may be explained by this model as it accounts for the effects of such variables as the presence of a distractor task, the rate of presentation, and the list length. The recency effect is explained by the fact that the last items are still in the buffer at the time of test. The primacy effect is explained by the fact that the first

items stay in the buffer longer than subsequent items. Because the buffer starts out empty, subsequent items do not displace the initial items until the buffer is full. Most crucial are the model's explanation of why some variables have different effects on the prerecency and the recency parts of the SPC. It is assumed that when a distractor task, such as mental arithmetic, is interpolated between list presentation and recall, the last items of the list are immediately displaced from the buffer, which does not contain any item at the time of recall.

However, the modal model interpretation of the SPC may be challenged because recency effects have also been found for LTS memory performance. First, a recency effect has been demonstrated in students' recall of the names of the presidents of the United States [34]. Second, a recency effect has been found for rugby team members' recall of the teams they played against that season [4]. Third, a recency effect has been discovered in the continuous-distractor paradigm, in which a distractor task follows the presentation of each item in the list including the final item[10]. This suggests that recency reflects a temporary rehearsal buffer instead of an automatic STS function.

Nevertheless, it has been argued that these empirical challenges to the modal model interpretation of the SPC can be dismissed [20]. Not all 'U'-shaped SPC's have the same specific shape or the same underlying causes. For example, the shape of the SPC for the recall of presidents' names has a much larger recency effect than is typically found in free recall tasks. The latter argument may, however, be questioned as it is based on the faulty premise that shape and function are strictly coupled. Raaijmakers [30] for instance pointed out that the modal model does not imply that STS is the cause of all recency effects. Part of the advantage for recency items can be predicted by the modal model from the fact that retrieval from LTS is often based on cues from the current context, and the recency items are more closely linked to the current context than are earlier items. This interpretation of the data makes the modal model a mere descriptive model.

The recency effect of free recall has been explained in terms of a simple temporal or ordinal discrimination hypothesis, in that recency reflects registration in implicit memory by a priming process [5]. It has been proposed that recall involves reactivating nodes for items in a network and those more recent items are primed and thus reactivated more easily. Using Tulving & Schacter's [39] five criteria of priming they found support for the following facts: (a) intact performance in amnesia for recency items, (b) developmental dissociation between recency items and the rest of the list, with no developmental effect on recency items, (c) drug dissociation between recency items and the rest of the list, with no effect of drugs on recency items, (d) functional independence, whereby recall of earlier list items is influenced by different factors than is recall of recency items, and (e) at least some hint of stochastic independence whereby initial recall of recency items is independent of their subsequent recall from LTS. Baddeley & Hitch [5] argue further that although recency reflects implicit learning, an explicit retrieval strategy is used to output first the last items.

Another theoretical explanation of the SPC has been that the recency part is associated with automatic availability of information requiring little attention, whereas the prerecency part is associated with the utilization of controlled or effortful attention-directing activity [2,13,19,25,28,36]. Automatic processing is believed to function without attention, to occur without intention, and not to improve with practice. Effortful processing is believed to seize a large part if the limited attentional capacity, to occur intentionally, and to improve with practice [19,36]. Examples of automatic processing are a sense of time and space, fluent reading or writing, while examples of controlled or effortful processing are rehearsal, organization, and mnemonic techniques. Clinical neuropsychological research also suggests that two different memory functions underlie the SPC of single-trial free recall, since memory performance on the prerecency and recency part is impaired by lesions of different areas of the brain. It has been found that patients with amnesia, Parkinson disease, as well as alcohol-intoxication, show impaired

performance on the prerecency part [6,8,22]. Epileptics, on the other hand, show poor performance on the recency part [31]. It has also been found that impaired verbal performance on the prerecency part is associated with large left hippocampal removal while the recency part is associated with damage to the left inferior parietal area [7, 30, 35].

As far as multi-trial free recall is concerned, there is evidence that two similar memory functions underlie the SPC of multi-trial and single-trial free recall. Multi-trial free recall is attained when a list of words is presented in the same or a different order several times over. It differs from single-trial free recall as the formation and strengthening of positional and sequential associations [23]and subjective organization [37] is facilitated, complicating study of the serial position effect, on which the theoretical interpretation in terms of the modal model is based. In spite of this complication it has been found that hippocampal damage is associated with impaired recall performance on the prerecency part for both single-trial as well as multi-trial free recall [21,30], suggesting that similar functions are active.

One way to determine whether similar functions are active in the SPC of single- & multi-trial free recall is to make use of factor analysis, a statistical technique used to identify a relatively small number of factors that can be used to represent relationships among sets of many interrelated variables. Factor analysis helps to identify these underlying, not directly observable, functions, and avoids the problem of confusing shape with function.

To the best of our knowledge only one study has been published where this technique has been used [14]. However, not free recall but serial recall was studied in a relatively small group of normal and retarded children and adolescents who were offered lists of different length and subsequently first-choice correct responses were asked of positions an item took in a list. Using Principal Components Analysis (PCA) and varimax rotation it was found that two factors underlie the SPC of single-trial serial recall, although no

evidence was found implying that the prerecency part and the recency part underlie different functions.

As far as we know free recall has not been studied by means of factor analysis. To this end routine free recall data of very large groups of heterogeneous psychiatric patients were used. We hypothesized that, in single- as well as multi-trial free recall, the recency part underlies one factor and the prerecency part the other.

EXPERIMENT 1

Method

Participants

Free recall data were used from routine neuropsychological screening of a heterogeneous group of 467 (193 M, 274 F) psychiatric inpatients, mean age 60.4 sd ±18.5 yrs, range 17–91 yrs; TIQ 93.5, sd ± 15.3, range 57-142; MQ 84.6, sd ± 20.0, range 50 –143. Age characteristics of the group of participants are: 38 between 17-30 yrs, 34 between 30-40 yrs, 55 between 40-50 yrs, 62 between 50-60 yrs, 85 between 60-70 yrs, 127 between 70-80 yrs, and 5 between 80-91 yrs. Intelligence quotients were determined by means of the Wechsler Adult Intelligence Test (Wechsler, 1955, 1981). Memory quotients were determined by means of Wechsler Memory Scale (Wechsler, 1945, 1987).

Materials

The test used is a modification of the Rey Auditory Verbal Learning Test (RAVLT) [9,32]. Preceding the standard presentation of the RAVLT, that is five presentations and free-recall of fifteen words, five presentations are offered and immediate recall is asked of the first six words and followed by the same procedure for the remaining nine words. Words are read at a speed of 1.5 sec per word, and are always presented in the same order. Recall is oral.

Procedure

Before starting the test the following instruction is read to the subject: 'Aim of the following test is to learn fifteen words. This will be done in three steps. First, six words will be presented five times and after every presentation free-recall will be asked. Immediately thereafter the remaining nine words will be presented five times and again free-recall will be asked after every presentation. Finally, the fifteen words list will be presented five times and again free-recall will be asked after every presentation. You are free to recall in any order. Is that clear? Ok let's start'.

After the 6-word list has been presented and recalled five times, the subject is told: 'Now we will go on to the 9-word list', and after the 9-word list is presented and recalled five items: 'Now we will go on to the 15-word list, that is the 6- and 9-word list in aggregate.' Rank order of recall was recorded.

In the first factor-analyses (single-trial and multi-trial free recall) items were given dichotomic values of 1 or 0, for being recalled or not. In multi-trial free recall the times each item was recalled over five trials was used as a measure. For factor-analysis using rank order information we assigned values to the items recalled, that were related to their probability of being recalled. The first item got the highest possible value (6,9 or 15 depending on the list length), the second item recalled got one value lower (5,8 or 14) etc., and the values that were not recalled got the value 0.

SPC's of single-trial free recall and multi-trial free recall, i.e. the means of the times an item is recalled after one and five presentations were calculated. A single factor analysis on data from all three lists was performed. Principal Components Analysis (PCA) was used to extract components. As rule-of-thumb components with eigenvalue>1 was used. If, however, more than two components with eigenvalue >1 were found, only the first two components were rotated. Oblique rotation was used, as there is evidence that the two processes, which are hypothesized to underlie the prerecency and the recency part, are related [44]. Factor loading less than .3 were not considered as substantial [26].

Results

The SPC's of multi-trial free recall show clear-cut primacy and recency effects. Multi-level analysis of the SPC's multi-trial free recall shows a parabolic shape for the 6- and 9-word list. This also holds true for the 15-word list when positions 7 and 11 are excluded. This implies that the serial position effect is still active. In the SPC's of single-trial free recall of the 6- & 9-word lists primacy and recency effects were hardly discernable. Elevated recall in position 7 of the 15-word list, the first item of the previously learned 9-words list may be

explained by the fact that the beginning of a list is rehearsed more frequently.

The SPC's of multi-trial free recall of the three lists are depicted in fig. 1.

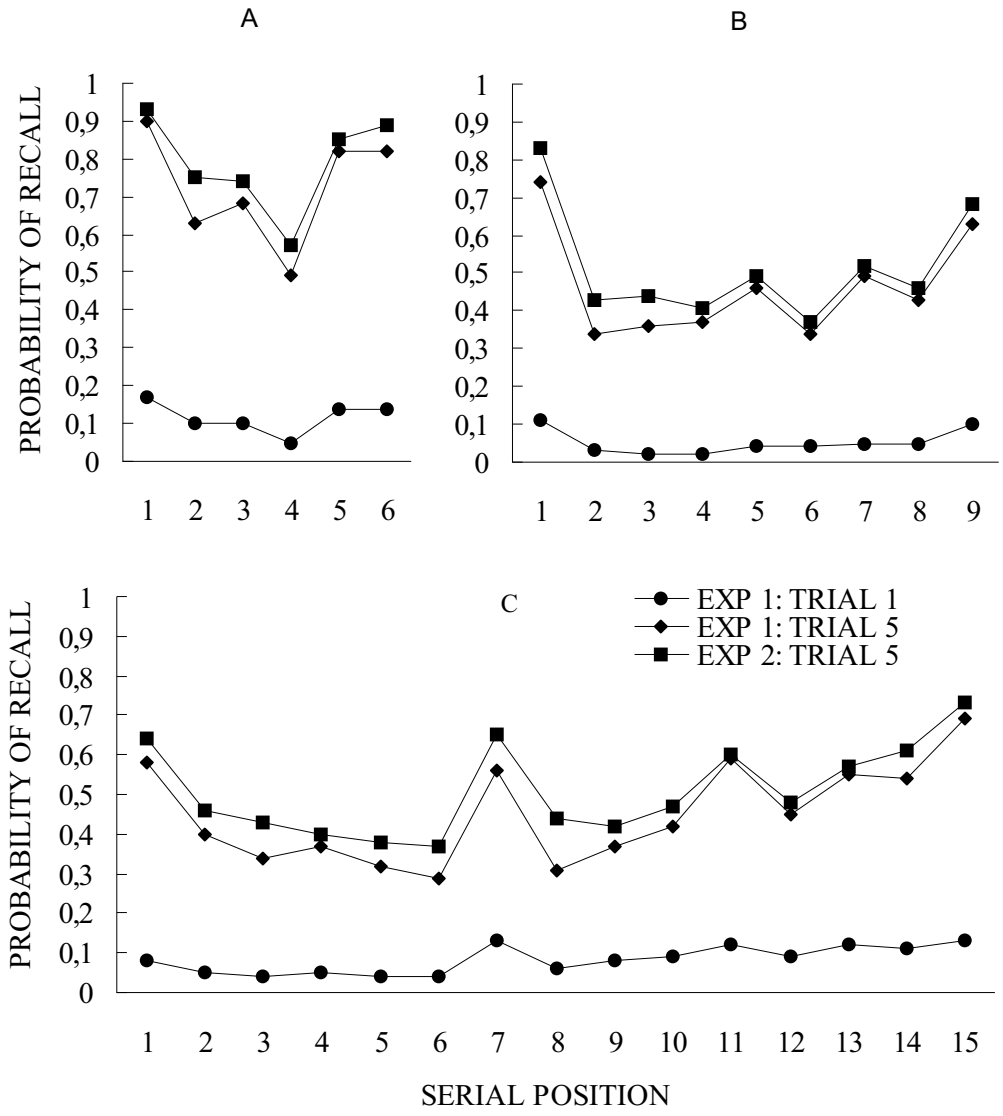

Figure 1 A, B, C The serial position curves of single- & multi-trial free recall of the 6-, 9-, and 15-word lists of Experiment 1 & 2

Factor analysis of single-trial free recall

Factor analysis of single-trial free recall was restricted to the 6 & 9-word lists as a

whole, since first recall of the 15-word list cannot be regarded as an SPC of single-trial free recall. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is .60. PCA extracted six components with eigenvalue >1 (see table 1).

TABLE 1

Eigenvalues

	Experiment 1		Experiment 2	
Factors	Single-trial	Multi-trial	Rank order recall 9 word list	Multi-trial
1.	2.26	9.5	5.8	9.1
2.	1.52	2.2	3.5	2.0
3.	1.39	1.4	2.7	1.7
4.	1.26	1.3	2.3	1.4
5.	1.12	1.2	1.9	1.3
6.	1.02	1.0	1.7	1.1

Eigenvalues larger >1 of single- & multi-trial free recall of the 6-, 9- and 15-word lists as a whole and rank order of recall of the 9-word list in Experiment 1, and of multi-trial free recall of the 6-, 9- and 15-word lists as a whole in Experiment 2

When the first two components were subjected to oblique rotation it is found that one factor underlies the recency part and the other the prerecency part (see table 2). As the shape of the SPC's clearly lack primacy and recency effects, this confirms that shape and function are not strictly coupled. The correlation between the two factors is .14. The first component explains 15.1% and the second explains 10.1 % of the variance.

Factor analysis of multi-trial free recall

The KMO-measure is .91 for the three lists as a whole, which according to Kaiser [24] justifies factor analysis. PCA shows that six components with eigenvalue >1 may be extracted from the data of the 6-, 9- and 15-word lists (see table 1). Applying the postulates

of factorial causation and of parsimony the first two components were used for further analysis. After oblique rotation it was found that one factor underlies the recency part and the other the prerecency part of each list (see table 2).

The correlation between the two factors is .47. The first factor explains 31.8% of the variance, the second factor 7.4 %. A critique one may have is that serial correlations between the data points may account for the observed trends. However, checking the correlation matrices it was found that serial correlations do not dominate over other correlations between data points.

Factor analysis of rank of recall over five trials

The differentiating effect of adding rank order information to the factor-analysis was only analyzed for the 9-word list. Again a sufficient KMO- value, .68 was found justifying factor analysis. PCA extracted nine components with eigenvalue >1 (see table1 where only the first six are listed). When the first two components were subjected to oblique rotation it was found that one factor underlies the recency part and the other the prerecency part (see table 3).

The correlation between the two factors is – 0.09, which is very small, indicating that they are orthogonal and independent of each other. The first component explains 12.8% of the variance the second 7.7 %. To ensure the validity of the present findings we repeated the study. We again hypothesized that in multi-trial free recall i.e. one factor underlies the recency part, the other the prerecency part.

TABLE 2 Factor analysis: Free recall

	Experiment 1				Experiment 2	
	Single-trial		Multi-trial		Multi-triall	
	Factors					
	1	2	1	2	1	2
S6pos1	.53		.60		.52	
S6pos2	.35		.68		.60	
S6pos3	.43		.54		.58	
S6pos4			.56		.60	
S6pos5				.52	.32	
S6pos6	.46			.51	.32	
S9pos1	.70		.72		.58	
S9pos2	.51		.71		.68	
S9pos3			.48		.59	
S9pos4	.51		.65		.61	
S9pos5	.39		.49		.51	
S9pos6			.52		.45	
S9pos7		.70		.66		.66
S9pos8		.64		.62		.66
S9pos9		.71		.72		.72
S15pos1			.73		.69	
S15pos2			.64		.61	
S15pos3			.63		.65	
S15pos4			.60		.70	
S15pos5			.67		.62	
S15pos6			.56		.61	
S15pos7			.44		.49	
S15pos8			.71		.69	
S15pos9			.37		.49	
S15pos10			.57		.69	
S15pos11			.40		.42	
S15pos12			.52		.56	
S15pos13				.68		.58
S15pos14				.63		.65
S15pos15				.66		.67

Factor analyses of single- & multi-trial free recall of the 6-, 9-, and 15-word lists as a whole in experiment 1, and of multi-trial free recall of the 6-, 9-, and 15-word lists as a whole in Experiment 2
Note: Loading < 0.30 is omitted

TABLE 3 Factor analysis: Rank order of recall

	Experiment 1									
	Trial1		*Trial2*		*Trial3*		*Trial4*		*Trial5*	
	Factors		*Factors*		*Factors*		*Factors*		*Factors*	
	1	2	1	2	1	2	1	2	1	2
S9pos1	.67		.51		.49		.47		.51	
S9pos2	.39		.46		.50		.37		.41	
S9pos3			.31		.44		.37		.43	
S9pos4	.37		.43		.51		.52		.57	
S9pos5							.33		.37	
S9pos6										
S9pos7		.36		.40		.45		.46		.32
S9pos8		.42		.54		.48		.56		.49
S9pos9		.57		.61		.54		.55		.57

Factor analysis of rank order of recall of the 9-word list over five trials in Experiment 1 *Note*: Loading < 0.30 is omitted

EXPERIMENT 2

Method

Participants

Free recall data was used from routine neuropsychological screening of a heterogeneous group 620 (308 M, 312 F) psychiatric patients, mean age 50.3 sd ±18.9 yrs, range 17–90 yrs; TIQ 96.1, sd ± 15.6, range 55-137; MQ 89.7, sd ± 20.9, range 50 –143. Age characteristics of the group of participants are: 92 between 17-30 yrs, 104 between 30-40 yrs, 114 between 40-50 yrs, 89 between 50-60 yrs, 77 between 60-70 yrs, 96 between 70-80 yrs, and 38 between 80-91 yrs. About half of the subjects (N=276) were substance abusers treated at the Brijderstichting (Alkmaar, the Netherlands). The other half of the subjects (N=344) was a patient sample of the Rijngeest Group, location Oegstgeest, the Netherlands. Intelligence quotients were determined by means of the Wechsler Adult

Intelligence Test (Wechsler, 1955, 1981). Memory quotients were determined by means of Wechsler Memory Scale (Wechsler, 1945, 1987).

Materials and Procedure

Materials and Procedure were the same as in experiment 1.

Results

As can be detected the SPC's of multi-trial free recall show clearcut primacy and recency effects. Again the SPC's multi-trial free-recall show a parabolic shape for the 6-, 9- and 15-word list after multi-level analysis, when in the latter list positions 7 and 11 are excluded, implying serial position effect. Again elevated recall in position 7 of the 15-word list may be explained by the fact that the first items in a list are rehearsed more frequently.

Factor analysis

The KMO-measure is .91, which according to Kaiser [24] justifies factor analysis. PCA shows that six components with eigenvalue >1 may be extracted (see table 1).

Applying postulates of factorial causation and the postulate of parsimony, the first two components were used for further analysis. After oblique rotation it was found that one factor underlies the recency part and the other the primacy and middle part (see table 2). The first component explains 30.3% of the variance, the second 6.7 %.

DISCUSSION

In accordance with our hypothesis we found in the first study that in single- as well as multi-trial free recall one factor underlies the prerecency part, and the other the recency part, and confirmed this finding for multi-trial free recall in the second study. This is consonant with neuropsychological findings [7,11,22,30,31,35]. To the best of our knowledge this is the first study where this is demonstrated by means of factor analysis.

Factor analysis using information related to the rank order of recalled items supports and

further differentiates this partitioning, and in addition shows that with each trial more words load on the prerecency factor. This is in line with the modal model interpretation of the SPC [1,15], and suggests that they are placed in the LTS. On the other hand, from the first trial on to the fifth trial the last three words load significantly on the recency factor suggesting that these words are in the STS. The combination of the two factors suggests that the subjects initially output the items still remaining in the buffer and then make a fixed number of searches of LTS. As no item loaded significantly on both factors the assumption that an item may be retained in the STS buffer as well as the LTS at the same time is not supported.

Also counter to the assumptions of the modal model is the finding that the last three items still load on the recency factor, even after ten trials, which is the case in the 15-word list. According to the modal model these words would have been long time placed in the LTS and thus in other words load on the prerecency factor. Evidently this is not the case, implying that even more rehearsal is needed or that an alternative explanation is necessary.

One alternative explanation may be that the SPC of single- as well multi-trial free recall is representative of STS memory performance and that the prerecency and recency part underlie activation of subsets of LTS memory by means of effortful and automatic processing. This becomes clear when the following two arguments are combined. First, it has been argued that the recency part is associated with automatic availability of information requiring little attention, whereas the prerecency part is associated with the utilization of controlled or effortful attention-directing activity [2,13,19,36,37]. Second, it has also been argued that STS memory performance is equivalent to activation of subsets of LTS memory by means of effortful and automatic processing [12]. Since Roediger and Crowder [31] and Baddeley and Hitch [3] also studied retrieval from the LTS, this may explain why they found a recency effect in students' recall of the names of the presidents of the United States and for rugby team members' recall of the teams they

played against that season. Our design may be regarded as similar, since the words that had to be retrieved were high-frequency words, which we have to assume, are already present in the LTS.

In a recent study [8] we found evidence in accordance with this line of reasoning. Memory impairments in depression have been explained as problems with effortful processing [18]. Departing from the assumption that the prerecency part is associated with effortful processing [2,13,19,25,27,36] we found impaired memory performance on the primacy part in a group of depressed inpatients.

If we equate the size of the recency factor to the buffer, which was estimated to be four items large [1], the results of this study suggest that the buffer has a size of two to three items for the particular words and lists we used. This is similar to earlier assessments of the recency part where it was assessed to be two to four items [16, 17].

In addition, we found in the second study evidence in support of the modal model interpretation of the SPC [1,15]. This may be deduced from the fact that the last two items of the 6-word list now load on the prerecency factor, suggesting that these items are placed in the LTS. This further corroborates the claim by Laming [29] that the SPC is not representative of two stores as it suggests that it depends upon the amount of rehearsal whether the SPC is representative of one or two stores.

A critique one may have on this study is that we studied heterogeneous group of psychiatric patients, when memory performance on the prerecency and recency part is dependent upon the type of illness. Yet, the aim of the present study was to demonstrate by means of factor analysis, using the greatest amount of variability, that the factors proper are not affected by whatever illness, even though the illness proper may differentially impair memory performance on these parts.

In conclusion, this is the first study where by means of factor analysis it is demonstrated that the SPC of single & multi-trial free recall underlies two factors, one associated with the prerecency part, the other with the recency part.

Acknowledgements

I would like to thank J. Schijf, MA for access to the data of patients of the Brijder Stichting, M.M.van Deemter BA for data gathering, and Prof Dr J. Raaijmakers for his critical remarks.

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