EVALUATION BATTERY FOR SEMANTIC MEMORY DETERIORATION IN ALZHEIMER

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This work presents a battery or series of tests that were designed with the aim of assessing the deterioration of semantic and/or conceptual memory in patients with Alzheimer's disease. Specifically, our aim is to evaluate knowledge of certain semantic categories, relating to living things and inanimate objects, as well as the attributes or characteristics that structure and organize them. In this article, the eight tests that make up the battery are described in detail, explaining not only their structure, composition, and application, but also the theoretical-conceptual assumptions that support them. The tests evaluate fluidity of category examples, definition, naming, attribute recognition, matching pictures-spoken words, true-orfalse sentence verification, analogies, and classification. Finally, the results of the factor analyses performed on the data obtained from a sample of 75 subjects (30 control and 45 Alzheimer's patients) are described, and we evaluate the construct validity of this battery, which measures what it was intended to measure: lexico-semantic knowledge of natural categories and objects categories.

El presente trabajo presenta una batería o conjunto de pruebas que se han elaborado con la finalidad de poder evaluar el deterioro de la memoria semántica y/o conceptual en pacientes con Alzheimer. Más en concreto, pretende evaluar el conocimiento de determinadas categorías semánticas referentes a seres vivos/animados y seres vivos/objetos, así como los atributos o características que las estructuran y organizan. En este artículo se describen minuciosamente las ocho pruebas que componen dicha batería, explicando de cada una de ellas no sólo su estructura, composición y forma de aplicación, sino también los supuestos teórico-conceptuales que les sirven de soporte. Las pruebas evalúan fluidez de ejemplares de categorías, definición, denominación, reconocimiento de atributos, emparejamiento palabra-oída/dibujo, verificación de la verdad o falsedad de enunciados, analogías y clasificación. Para finalizar se describen los resultados de los análisis factoriales que se han llevado a cabo con los resultados obtenidos a partir de una muestra de 75 sujetos (30 controles y 45 Alzheimer) y se evalúa la validez de constructo de esta batería que mide lo que pretender medir: conocimiento léxicosemántico de categorías naturales y de objetos.

The study of the organisation, structure and functioning of semantic or conceptual memory, together with the representation of knowledge, constitutes a central concern of cognitive psychology. In recent years, moreover, the ever more profound knowledge being acquired of disorders resulting from a series of Central Nervous System pathologies has revealed that one of the most frequent types of deterioration affects the semantic memory system, so that this area has become an object of priority interest on the part of cognitive neuropsychology. The study of different types of patient affected by dementia (Alzheimer's, Pick, Lewy bodies, etc.) has demonstrated, among other things, the existence of a series of dissociations and double dissociations between semantic categories, selective loss of stored information, and other types of syndrome that affect the semantic system. A new syndrome has even been defined: semantic dementia. Nevertheless, there is far from unanimity on the explanation of these disorders.

The study of patients with dementia of the Alzheimer type (DAT), due to a series of factors in their illness, basically the gradual and total deterioration of their semantic memory due to the diffuse neurological damage they present, may help to clear up many of the mysteries surrounding this type of dementia.

On the basis of the above, our research team designed a set of tests, which we shall refer to tentatively as Evaluation of Semantic Memory in patients with Dementia of the Alzheimer Type (EMSDA, *Evaluación de la Memoria Semántica en pacientes con Demencia tipo Alzheimer*), whose purpose is the evaluation of the deterioration of a highly important aspect of semantic

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memory: knowledge of natural categories and objects (living and non-living entities, biological and non-biological categories), as well as the attributes or characteristics that provide the basis of their conceptual organisation.

This knowledge is evaluated by means of verbal tests – of production and comprehension – and non-verbal ones, involving not only linguistic but also visuo-perceptual knowledge, and which we shall analyse in detail below.

All of the stimulus items or categories to which these tests refer were selected according to norms of typicality of categories (within the framework of that which is available in scientific literature in Spanish – Soto, Sebastián, García and Del Amo, 1994), and belong to two levels of generality: superordinate and basic, and to two large categories, living things and non-living things. Moreover, the evaluation of the attributes or characteristics was carried out in accordance with a model of conceptual representation designed on the basis of empirical data from large samples of subjects, with which some of our team have been working for a number of years (Peraita, Elosúa and Linares, 1992; Peraita, Linares and Elosúa, 1990).

From a practical point of view, this set of tests complements the more or less classical neuropsychological and mental examination, in which semantic evaluation is not well represented, and its use may be of great predictive value, since it makes possible the detection of certain semantic pathologies in their earliest stages.

DESCRIPTION OF THE BATTERY

Fluency of exemplars of semantic categories

This test aims to evaluate the subjects' capacity for generating in a given time a series of types or exemplars belonging to the semantic category they are given as a point of reference. It can also be used to evaluate the underlying organisation of these exemplars in semantic memory. It is therefore a test of both, on the one hand, verbal fluency and/or restricted production, and, on the other, of knowledge of cognition of categories, as a reflection of their underlying organisation in semantic memory.

The reason for the inclusion of this type of test in the battery is that one of the first behavioural symptoms in Alzheimer's disease is the inability to find and retrieve spontaneously certain words, in addition to a significant reduction in categorical lexical availability (Henderson, 1996; Martin and Fedio, 1983; Weingartner, Kawas, Rawlings and Shapiro, 1993). In consequence, this test may be of enormous value in predicting an incipient deterioration in the subject's production system. Furthermore, given the existence of neuropsychological studies that have found certain dissociations between categories of living and non-living beings, or animate and inanimate objects (Gonnerman, Andersen, Devlin, Kempler and Seidenberg, 1997), it would seem appropriate to try and discover whether the verbal production of exemplars of semantic categories belonging to the mentioned types are affected differentially in terms of production rate and underlying semantic organisation. Finally, one of the computational models of categorisation is the so-called exemplars model, which maintains that we make categorical decisions (that is, of inclusion of exemplars in classes) as a function of the number and type of exemplars stored in memory with which we have had previous contact, and that it is by means of a computation of the similarity between them (those that we meet and those that we have stored) that we decide whether or not an exemplar forms part of a category. The organisation of our categorical system would depend, therefore, on the specific exemplars stored, and not so much on their attributes, as prototype-based models suggest (Brooks, 1987; Heit and Barsalou, 1996; Medin and Shaffer, 1978; Nosofsky, 1988).

The categories in this test belong to the superordinate level, as regards generality, and are: animals, item of clothing, plants, vehicles and furniture; the task is one of production, and the duration of the test is two minutes for each word, i.e., ten minutes in total. The instruction is: "Tell me all the animals you can remember", informing the subject of the time available.

A point is scored for each exemplar produced that actually belongs to the category, and a total calculated for each category. Incorrect items are disregarded. Different terms for the exemplars are accepted (e.g., ass and mule).

Conceptual definition of categories

The aim of this test is to evaluate the subject's semantic knowledge of a series of categories, through his or her ability to give as complete a conceptual definition as possible of given semantic categories. By conceptual definition we understand verbal production that contains conceptual elements or components (attributes, characteristics) corresponding to a series of aspects of the meaning of those categories (considering "meaning" in a wide sense). The conceptual components for which subjects are expected to produce attributes refer to: the generic class of inclusion of the category (e.g., a chair is an item of furniture), the parts of which it is composed (e.g., a chair has a back, a seat and legs), its function or use (e.g., a chair is for sitting on), the context/habitat in which it is normally found (e.g., chairs are found in the rooms of houses), physical evaluative dimensions (perceptual: form, colour, size, texture), social and affective evaluative dimensions (goodness, pleasantness), types or exemplars it includes (e.g., there are kitchen chairs, office chairs, bar chairs, etc.) and the agent that produces or generates it (e.g., they are made by a carpenter, etc.)

The reason for selecting categories belonging to two levels of generality is to allow two different types of hypothesis to be checked. The first of them comes from classical cognitive psychology (Rosch and Mervis, 1975; Rosch; Mervis, Gray, Johnson and Boyes-Braem, 1976), and maintains that people know more attributes of the basic level categories than of the more general or superordinate ones. The second hypothesis comes from current neuropsychological literature, and maintains that the most specific categories deteriorate and are lost most rapidly. The order of deterioration would be, therefore, first, subordinate categories, second, basic level categories, and third, superordinate categories.

Given that, as mentioned above, we start out from a previous model or scheme of conceptual definition of semantic categories both for living and non-living entities (Peraita, Elosúa and Linares, 1992; Peraita, Linares and Elosúa, 1990), we shall assign each of the conceptual elements produced by the subject to one of the slots of that scheme.

The categories to be defined in this test belong to two different levels of generality – superordinate and basic level – and to six semantic categories. Those corresponding to the first level of generality are: clothing, animals, vehicles, plants, fruit and furniture, that is, three "living" categories and three "non-living" ones. Those of the basic level are: trousers, dog, car, pine, apple and chair. We believe, moreover, that this conceptual scheme represents a detailed analysis of a theoretical nature (as well as a working hypothesis) with respect to the types of attributes that make up the categories and concepts, and goes beyond the analysis of attributes of categories that form the basis of recent cognitive neuropsychology studies, which, on attempting to interpret the dissociations between "living" and "inanimate" categories, reduce them to just two groups: perceptual and functional or associative (Farah and McClelland, 1991; Sartori, Miozzo and Job, 1993). Correct answers are scored with a 1 and errors with a -1, with errors being subtracted from correct answers to obtain a total score per category.

Picture-naming

This task aims to test the semantic search and reproduction process in the area of production. It checks the subject's ability to pass from auditory representation to selection of the corresponding item. Given that the stimuli are presented in the form of pictures, they are concrete objects, and therefore belong to the basic level of the category.

A well-documented finding in psychological literature is the sensitivity of the naming task to linguistic and conceptual difficulties. Difficulties related to inability to find the word sought – the well-known "tip of the tongue phenomenon" – are usually considered as mild manifestations of difficulties for finding words, or anomia whose maximum expression can be found in the behaviour of aphasic or amnesic patients or those with Alzheimer's disease.

More specifically, naming tasks that use drawings as test stimuli are especially useful in the case of disorders with a strong semantic component, and can be used in quite adverse conditions (e.g., with illiterate subjects) and with a wide variety of populations.

The naming task traces the process that occurs from the moment the subject has the intention of emitting a word until its actual emission. It therefore registers the mechanisms involved in that process (basically, access to and retrieval of semantic information and access to and retrieval of phonological information).

The more traditional studies (Caramazza and Berndt, 1978; Gardner, 1973; Goodglass and Geschwind, 1976) that used the naming task defended the hypothesis of difficulties in access to/retrieval of semantic information, specifically in aphasic patients. Subsequently, the errors committed by patients on attempting to emit the correct answer led researchers to propose an alternative hypothesis: deficits in semantic knowledge itself (Butterworth, Howard and McLoughlin, 1984; Gainotti, Silveri, Villa and Miceli, 1986). More recently, these later models have been taken up by researchers in DAT (Bayles and Tomoeda, 1990) for specifying the two basic hypotheses of the semantic deficit: disorders of attributes versus alterations of the category. Over roughly the last twenty years, the naming task has been the most commonly used.

Studies frequently use retrieval cues for checking the sensitivity of the mechanisms underlying external information. A comparative study (Rochford and Williams, 1962) showed that the phonetic cue (the initial part of the word) is the most powerful of all the cues. In this regard, it is relevant to mention a Spanish study with anomic patients that found the same result: all anomic patients benefited from the phonetic cue (Sánchez Bernardos, 1988); earlier, Pease and Goodglass (1978) had referred to anomia as the syndrome most favoured by cues of this type.

The task comprises 36 items, six high-typicality items for each of the following six semantic categories: animals, fruit (vegetables), vehicles, furniture, plants and clothing. As the animals category was the largest, for the selection of the items it was subdivided into vertebrates and invertebrates. From the former group were taken exemplars of mammals (dog), birds (canary), reptiles (lizard) and fish (sardine), and from the latter an insect (fly), as high-typicality elements, as well as a mediumtypicality mammal (monkey). Plants, in turn, were subdivided into trees, flowers and bushes. For the category of fruit, apart from the typicality criterion, an additional criterion was used, that of being distinguishable from one another.

Correct answers without cue were computed with a value of 1 point, correct answers with cue with a value of 0.5, the superordinate category with 0.8 and errors with a value of -1.

Recognition of attributes

This test has a dual purpose: first, to attempt to confirm the controversial categorical dissociation between living and non-living entities, and second, to check differential deterioration of types of attribute, which, in turn, and according to recent neuropsychological literature, depends on the deterioration of certain semantic categories (Farah and McClelland, 1991; Gonnerman, Anderson, Devlin, Kempler and Seidenberg, 1997; Sartori and Job, 1988; Sartori, Miozzo and Job, 1993; Warrington and McCarthy, 1987; Warrington and Shallice, 1984).

As it can be seen, this test is complementary to the second one, the conceptual definition of categories, since, once again, the aim is to evaluate subjects' knowledge of different types of conceptual components or attributes that supposedly make up the categories, but which, due to difficulties of verbal production in some subjects since the onset of the illness, may not have appeared in the free or spontaneous definition. The test is based on the assumption that, on certain attributes being explicitly elicited by the experimenter in a comprehension test, subjects may demonstrate their knowledge of them (Cox, Bayles and Trosset, 1996).

There are common attributes or components that refer to categories of living and non-living entities, and other specific ones for each of these categories. The common ones are: taxonomic, functional, part-whole, evaluative, location/habitat, types. The specific ones are: procedure, behavioural activity, cause/generation and source or origin. The taxonomy of attributes that serves as a theoretical and methodological framework for this test, as in the second test, can be seen in detail in Peraita, Elosúa and Linares (1992).

The number of categories presented in this test is twelve, six referring to objects (chair, car, trousers, shirt, table and bicycle) and six referring to living things: animals, plants and fruits (dog, apple, pine, canary, pear and rose). Correct answers score 1 point, and errors score -1, to be subtracted from the correct answers score.

The procedure for the application of this test is as follows. The subject is presented with each one of the items or names of semantic categories mentioned above, and for each one s/he is asked a series of brief questions, 4 in total, whose objective is to see whether the subject knows and can express verbally different types of semantic-conceptual relationships involved in the different questions. For example, for chair, subjects are asked. "What is a chair for?", "What are the parts making it up?", "What is it like?", and "Where is it normally found?". These refer, respectively, to the conceptual components: functional, part-whole, evaluative and place. So as not to make the task too long, even though a total of eight relationships are evaluated, for each category the subject is only questioned about four of them.

Matching pictures-spoken words

The task of matching spoken words with pictures can be considered as being to the area of comprehension what the naming task is to the area of production. In the naming task, the picture is shown so that the subject can give it a name, while in this task the name is given so that the subject can point to the corresponding picture. If in the former task the subject can make a mistake and give the wrong word, the present one aims to give the patient "various ways of making a mistake", in order to observe whether there is any pattern of "choice" in the type of error (i.e., whether s/he tends to choose a given distractor).

The matching task used in the present work consists in a modified version of that designed by Gainotti, Miceli, Calatagirone, Silveri and Masullo (1981) for normal children and of the study by Sánchez Bernardos (1988) with anomic patients. Whilst in these two studies the scope of possible error was wider, in the present version the distractors were prepared exclusively in relation to the semantic field: either they belonged to the same category as the target, or a contrasting category (if animate, then inanimate, and vice-versa), or they bore a perceptual similarity to it. In this regard it is noteworthy that the Italian group that designed the original task insisted on the so-called "visual hypothesis", according to which visual-perceptual knowledge would be codified as part of the meaning, so that identifying something as a member of a category depends, in part, on being able to use this type of knowledge.

The task includes two series of stimuli. The first series is made up of 18 high-typicality items, 3 items for each of the six categories that are the object of study of the present work. Given that the interest of this task resides, as we shall see, in the type of error committed, a second, more difficult series was prepared, so that if the subject resolved correctly the first series, or if s/he committed only 1 or 2 errors in it, s/he moved on to the second series of items. This comprised 9 low-typicality items (two animals, two vehicles, two plants, an item of clothing, a piece of furniture and a fruit).

Each card showed four pictures: the correct item (e.g., dog) and three distractors: one distractor belonging to the same semantic category (gender and species) (e.g., horse); a second one belonging to a different category (e.g., hammer), such that, if the target is a living being, this distractor will be inanimate, and vice-versa; and finally, a third distractor that either bears a perceptualvisual similarity to the target (e.g., bird – when target is aeroplane), or is a part of it (e.g., beak). These three distractors are mutually exclusive.

Target position is controlled so that it is different in each item, varying between the four possibilities. Likewise, the three distractors appear in different positions across the different items. Correct responses are given a score of 1 point, with an error in the same semantic category scoring 0.5 and in a different semantic category. -1. Perceptual errors score 0.75.

True-or-false sentence verification

This task aims to check knowledge of a series of conceptual relationships associated with basic-level categories belonging to the superordinate categories of living things (animals, fruits and plants) and non-living objects (vehicles, clothes, utensils and furniture). This test complements the second one, the definition of semantic categories, and the fourth one, recognition of attributes. Its aim is to evaluate and check subjects' knowledge of the conceptual components or relationships of the categories that may or may not have been generated in the free definition task, or that may (or may not) have been recognised in the recognition of attributes test.

Various studies have shown that subjects with Alzheimer's disease produce errors on evaluating sentences about categorical membership of a concept or the properties associated with that concept (Chertkow and Bub, 1990; Grossman and Mickanan, 1994). In fact, some authors maintain that there is selective deterioration in the information represented in specific categories, this deterioration being greater in the living beings categories than in those of inanimate objects (Montanes, Goldblum and Boller, 1995; Silveri, Daniele, Giustolisi and Gainotti, 1991). On the other hand, studies such as that of Smith, Faust, Beeman, Kennedy and Perry (1995) show that subjects with Alzheimer's do not differ significantly from normal subjects in the number of correct responses on verifying the properties of an object, though their reaction times are significantly higher when they evaluate objects with low typicality or with less dominant properties.

The verification task was designed with the aim of analysing the supposed deterioration of subjects with Alzheimer's according to whether the sentences referred to living or non-living categories, the typicality of the basic concepts and the type of conceptual relationship. The conceptual relationships evaluated in the true and false sentences for each category are grouped in four modalities: (1) taxonomic, or of inclusion in classes (e.g., a dog is a mammal), (2) part-whole (e.g., a car has wheels), (3) functional (e.g., a hammer is for knocking in nails), and (4) evaluative (e.g., the sea is blue) and the corresponding false versions (e.g., a dog is a bird, a car has gills, etc.). The task consists of a total of 48 sentences divided in three series of 16 items, the last series being the most difficult, given the lower typicality of the items. This last series is only presented if the subjects resolve correctly the first two, or if they make a maximum of two errors. In each series, half of the sentences are true and the other half are false, and within each series, half of the categories refer to living things and the other half to non-living objects.

The task is presented as a list of sentences that the experimenter reads one by one, and the subject has to say whether the sentence is true or false. Correct answers are given a score of 1 point, errors a score of -1; in the last series, correct responses receive 1.2 and errors -0.8.

Classification

The aims of this test are to evaluate subjects' ability to classify a series of items belonging to diverse categories and to analyse the nature of the classifications made (taxonomic, thematic or others).

The classification task has been studied in the context of aphasic patients with difficulties for naming objects. The general assumption is that, in addition to naming difficulties, there is a certain impoverishment or reduction of the semantic field (Goodglass and Baker, 1976), so that the two problems derive from a common lexicosemantic deficit.

The classification task can take a variety of forms, such as asking the subject whether or not a picture is a member of a category (Grober, Perecman, Kellar and Brown, 1980), or requiring the subject to classify stimuli or put them in order using the criteria s/he wishes (Zurif and Caramazza, 1976). While the results of these studies may be interpreted within the framework of theories such as that of Smith, Shoben and Rips (1974), based on the way in which subjects order stimuli, it is also possible to consider these results as indicators of conceptual deficits associated with lexico-semantic deterioration.

Given that this task has been used in the study of other neuropsychological disorders with semantic deficits, it is included here to check whether it can provide convergent evidence on the existence and characteristics of this disorder in Alzheimer's patients.

The categories employed, presented by means of pictures, are: animals, plants, items of clothing, furniture, vehicles and food, that is, two living things categories and four inanimate objects categories. In each category there are three items to classify (18 in total).

The test consists of two parts, semi-guided classification and free classification. In the former, items are introduced by means of an exemplar item from each one of the categories (6 in total), with the aim of indicating to the subject how to do the task. Subsequently, subjects must put in order the rest of the items (18) in these categories. As far as possible, the items belonging to each category were chosen from different subcategories within the more general one (e.g., a mammal, a bird and a reptile for the category of animals). In the case of subjects making more groups than the pre-established ones, they were encouraged to regroup the items so that all of them were placed in six categories. In all cases, items were low-typicality (e.g., seal, bellflower, coconut), in order to avoid a ceiling effect, which had been observed in pilot tests with high-typicality items.

In free classification, on the other hand, subjects were given total freedom to group the items as they thought fit. Subsequently, they were asked to verbalise the criteria they used for making the classes. In this case, the items were high-typicality (e.g., canary, pine, apple).

Semantic analogies

The aim of the semantic analogies task is to study, in Alzheimer's patients, the processes of access to and retrieval of information previously stored in the memory and its use in the establishment of new relationships. In global terms, analogical reasoning is conceived as the transfer of part of the knowledge of a domain (source domain) to a different knowledge domain, which is similar in some aspects (target domain). This conception implies the existence of at least two distinguishable processes. On the one hand, the process responsible for retrieving the analogy, that is, retrieving the information relevant to the source domain, and on the other, the process responsible for applying that relevant information to the target domain.

Analogical reasoning is considered as one of the main cognitive processes involved in the use and acquisition of knowledge. According to Holyoak and Thagard (1989), the essential components of the human cognitive system include at least three basic subsystems: (1) a subsystem that permits the generation of inferences for the planning and achievement of objectives, (2), a memory subsystem which can be accessed for the selection of stored information relevant for the subject's specific situation, and (3) an induction subsystem through which new knowledge structures can be generated as the subject acquires more information in a given domain, and which in turn enriches the memory subsystem and increases the effectiveness of the subsystem for the generation of inferences. These three cognitive subsystems are interdependent, and analogical reasoning constitutes one of the best exemplars of this interdependence.

There have been many studies aimed at showing the facilitatory effect the analogy may have for establishing relationships between information and elaborating integrated and more comprehensible knowledge structures (Bransford, Franfs, Vye and Sherwood, 1989; Clement, 1988, 1991; Duit, 1991; Glynn, 1990, 1991; Klauer, 1989, Prawat, 1989; Vosniadou and Ortony, 1989). This facilitatory effect of analogy may be due to the fact that, through analogy, information becomes easier to retrieve, with improved recall of concepts due to a more complete retrieval of the relational information necessary for extracting an appropriate inference, as demonstrated in experimental studies such as those of Hayes and Tierney, 1982; Mayer and Bromage, 1980; or Schustack and Anderson, 1979.

We designed an analogical reasoning task that included the greatest possible number of the semantic relationships and the concepts and categories that formed part of the tasks used for studying categorisation. Specifically, we designed the task with three semantic relationships: (1) functional relationship, (2) part-whole relationship, and (3) taxonomic relationship. For each type of semantic relationship we generated six different problems, obtaining a total of 18 analogies. The last six analogies present a higher level of difficulty, as they contain concepts with lower typicality. This last series is only presented if the subjects correctly resolve the first 12 analogies, or if they commit a maximum of two errors.

The presentation of the semantic analogies was carried out using pictures, and in a multiple-choice format. The order of presentation of the different types of analogy and that of the two response alternatives were set at random. The patient was presented with a card showing the first three terms of the analogy (A:B :: C:) and requested to indicate which of the pictures corresponded to the fourth term of the analogy. Correct answers scored 1 point and errors, -1; in the last series, correct responses scored 1.4 and errors, -1.6.

METHOD

Description of the sample

A total of 75 subjects participated in the study, of whom 45 were diagnosed as probable Alzheimer's cases (DAT), and the other 30 were normal elderly people.

The sample of Alzheimer's patients was made up of 21 men and 24 women, with an age range of 54 to 93 years (mean age = 72.97). All the Alzheimer's patients were selected from various INSALUD (Spanish National

Table 1 Matrix of intercorrelations between the different factors (number of subjects in brackets)								
	NAMING	DEFIN	RECOGN	MATCH	VERIF	FREE	SEMI	ANALO
FLUID	.880 ^{***} (74)	.702 ^{***} (74)	.695 ^{***} (73)	.686 ^{***} (74)	.640 ^{***} (72)	.660 ^{***} (51)	.609 ^{***} (56)	.525 ^{***} (74)
NAMING		.666 ^{***} (74)	.648 ^{****} (73)	.698 ^{***} (74)	.643 ^{***} (72)	.642 ^{***} (51)	.600 ^{***} (56)	.543 ^{***} (74)
DEFIN			.676 ^{***} (73)	.759 ^{***} (74)	.740 ^{***} (72)	.617 ^{***} (51)	.422 ^{**} (56)	.527 ^{***} (74)
RECOGN				.714***	.804***	.722***	.523***	.443***
MATCH				(73)	(71) .801 ^{****}	(51) .610 ^{***}	(56) .526 ^{***}	(73) .571 ^{***}
VERIF					(72)	(51) .685 ^{***} (51)	(56) .556 ^{***} (56)	(74) .522*** (72)
FREE							.717 ^{***} (49)	.557 ^{***} (51)
SEMI								.328 ^{***} (56)
ANALO								. ,

= p<.01, *= p<.000

(FLUID: fluidity, NAMING: naming, DEFIN: definition, RECOGN: recognition, MATCH: matching, VERIF: verification, FREE: free classification, SEMI: semi-guided classification, ANALO: analogies).

Health Service) hospitals. The data basically referred to the NINCDS-ADRDA criteria and the score obtained in the Minimental State (MMS) (Folstein, Folstein and McHugh, 1975), in its Spanish version (Lobo, Escobar, Ezquerra and Diaz, 1980), which has been validated in the Spanish population. All subjects had been given the neurological and neuropsychological tests habitually employed in these cases, including the TAC, none of them manifesting any other pathology associated with their dementia. The group of patients with Alzheimer's included 24 subjects with scores ranging between 21 and 27 in the Minimental State, and 21 subjects with scores between 15 and 20 obtained in the Lobo version of the MMS.

The sample of normal elderly people was made up of 15 men and 15 women, with an age range of 55 to 85 years (mean = 76.41). Given that not all subjects always completed all the tests, the number of subjects is specified for each one, though in the majority of cases the number was 75 subjects.

RESULTS

The statistical analyses using mean scores with which we analysed the battery (set of 8 tests) were carried out with the SPSS version 7.5. Table 1 shows the correlation matrix between the 8 tests.

As it can be observed, all the correlations are significant and fairly high. Their range goes from r = .32, p<.001 (for the correlation between the Analogies task and the Semiguided classification tests) to r = .88, p<.001 (for the correlation between the Fluency and the Naming tests).

On the basis of this matrix, we carried out a principal components analysis (see Table 2). All tests were grouped within it, and it explained 70.71% of the total variance.

Furthermore, we analysed the changes produced in the percentage of explained variance as we eliminated tests that had not been answered by all subjects. Our aim was to arrive at the best factorial solution. These analyses showed that certain tests of the battery (Sentence verification, Matching, Verbal fluency, Definition of categories and Picture-naming, with respective factorial weights of .90, .89, .87, .86 and .85) constituted the most appropriate subset for the evaluation of lexico-semantic knowledge and conceptual relationships, explaining 72.81% of the total variance and considering information from the 75 subjects.

A factor analysis was carried out, taking together the

scores of the Alzheimer's group and those of the normal elderly group. With these results we found that the EMSDA battery discriminated perfectly between the two groups of subjects, and that also, within the Alzheimer's group, it discriminated patients in a mild phase of the disease and those in a moderate phase. Thus, the battery can be used not only to predict the disorder but also to predict its possible course. Similar results were also obtained using only five of the tests (tests 5, 6, 7, 8 and 9). All tests are grouped within one factor. A similar percentage of the variance explained is obtained with nine and five tests, and both options (nine and five) discriminate between Alzheimer phases.

The advantage of considering just 5 tests is that they contain the scores of all 75 subjects, whilst with all the tests it was necessary to eliminate some subjects (those that did not carry out all of them). In the former case (5; N = 75), healthy control subjects obtain a mean score of .90, whilst those with mild Alzheimer's obtain -.28, and those with a moderate level of the disorder, -.98. If we consider the mean score obtained on 9 tests, the healthy subjects obtain .57, the mild DAT subjects -.40 and the moderate ones -1.59. The two follow the same tendency.

The diagnostic capacity of the battery can be inferred from the value of the scores in each test and the fact of whether this value is within the maximum quintile, or within the high, medium, low or minimum one. No control subjects' score is in the low or minimum quintiles. Likewise, only 6.7% of the scores of the moderate DAT subjects is in the high or the maximum quintile, although the majority of them, 76.5% are in the minimum quintile. We also analysed the incidence of the disease, which is represented by the percentage of each group of subjects within those percentages whose factorial value is found in each quintile.

Table 2 Matrix of weights obtained for each test by a principal components analysis (decimals omitted)						
Sentence verification	90					
Matching pictures-spoken words	89					
Verbal fluidity	87					
Definition of categories	86					
Picture-naming	85					
Recognition of attributes	84					
Free classification	84					
Semi-guided classification	74					
Analogies	70					
Percentage of explained variance	70					

Finally, we carried out a discriminant analysis in an attempt to obtain four groups that were as differentiated as possible from one another. In this way, using four groups instead of those determined by the five quintiles, the diagnostic value of the battery can be clearly seen.

With regard to subjects' incidence in the four groups, we find that 60% of the healthy old people are in the optimum group, 30% are in the good group and just 10% in the medium group. Among the mild DAT group, no subject is in the optimum group, just 30.4% are in the good group, 52.2% in the medium group and 17.45% in the poor group. As far as the moderate DAT group is concerned, 4.5% are in the good group, 36.4% in the medium group and the majority, 59.16%, in the poor group.

Using the extreme groups created, we can diagnose the probability of having the disease or not. If a subject is situated in the optimum group, his/her probability of being healthy is 1 (all people in the optimum group are healthy), and of being ill with Alzheimer, zero (none of the subjects in the optimum group have Alzheimer). If, on the other hand, the subject is in the poor group, his/her probability of being ill at a moderate level is 0.76, and at a mild level, 0.23. There are two intermediate cases that indicate how a mild DAT patient has a probability of 0.41 of being situated in the good group, and how in a moderate patient this probability drops to 0.59.

DISCUSSION

This work has aimed to expose the theoretical and methodological foundations – based on current cognitive psychology – of each of eight tests making up the EMSDA battery, as well as to carry out a preliminary study of the battery based on the results obtained with 75 subjects in order to check its factorial structure.

The purpose of the battery is to analyse patterns of preservation/deterioration of lexico-semantic and semantic-conceptual knowledge, which can serve as neuropsychological markers of Alzheimer's disease, especially in its earliest phases (Dobato, Caminero, Pareja, Galeote and Peraita, 1998). The factorial solution obtained in the principal components analysis appears to indicate that this battery evaluates a single cognitive dimension that we might consider as semantic-conceptual knowledge.

As seen clearly from the results, all the tests contribute to the definition of a single factor, lexico-semantic or semantic-conceptual knowledge, which is extraordinarily positive, so that theoretically the battery could be reduced until it is made up of just one or two tests. However, such a simplification would not appear appropriate, since each one of the tests has peculiarities that bring into play different aspects of processing, not only according to the presentation mode of the items – verbal or visual –, but also because some involve production and others comprehension. In any case, work is currently being carried out to reduce not only the number of tests making up the EMSDA battery, but also the number of items included in each one of them, with the aim of saving time in their application and eliminating redundancy.

We consider the scoring system, of all those that would have been possible, to be based on three fundamental criteria: (1) It is not restricted to totalling hits and errors, penalising the latter; rather, its calculations are discriminative in accordance with aspects of item typicality, based on the assumption that the most frequent are the easiest to process, so that they score lower (tests 6 and 8); (2) where appropriate (test 3), a hierarchy of scores is established according to whether generated items belong to the basic or superordinate level, and to whether or not the observer provides cues for their generation; and (3) moreover, the type of category to which errors belong is taken into account (test 5).

The tests we designed coincide almost totally with those considered by various international research groups to be the most appropriate for this type of analysis of semantic deterioration. We feel, however, that their novelty and principal contribution, apart from the fact that no other study of this type exists in Spanish, derives from a series of aspects that give the set of tests a coherence and structured quality: 1) the balanced selection of the items making up each one of the tests (50% belonging to living things categories and 50% to inanimate objects categories); 2) the control of item typicality -based on the only production rules for category exemplars available in Spanish (Soto et al., 1994) - and the introduction in the majority of tests of two levels of difficulty according to that typicality; 3) the involvement of two input modes, since four are visual tests and four are verbal tests; and 4) the fact that 50%are production tasks and the other 50% are comprehension tasks.

In the covariance analyses carried out on the basis of each one of the tests to examine the effect of a series of factors (type of subject, sex, type of item, level of generality of items, conceptual relationships implied, etc.) on the way of dealing with the different tests described in this article, we have found unfailingly that healthy subjects behave in a significantly different way, in statistical terms, from those with Alzheimer's disease, and that within the Alzheimer's group, those mildly affected behave differently from those moderately affected, and in a consistent way across all the tests (Peraita and Sánchez-Bernardos, in press; Peraita, Galeote and González Labra, in press).

The same was found on analysing the data from the retest, carried out on 25 Alzheimer's subjects one year after the initial tests, for the mild cases, and six months after them for the moderate cases (Peraita, del Barrio, González Labra and Santana, 1999). In sum, we can claim to have developed an instrument that is unique in the Spanish language, and that permits the discrimination between Alzheimer's patients and healthy subjects, and between different levels of deterioration in Alzheimer's patients. Nevertheless, it would be interesting to repeat the test, or a reduced version of it, with a greater number of subjects, and to establish indicators on the basis of probability distributions.

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Example of a card from the naming task



Example of a card from the analogies task



Example of a card from the matching task