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Verb production during action naming in semantic dementia

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A B S T R A C T

In contrast with widely documented deficits of semantic knowledge relating to object concepts and the corresponding nouns in semantic dementia (SD), little is known about action semantics and verb production in SD. The degradation of action semantic knowledge was studied in 5 patients with SD compared with 17 matched control participants in an action naming task based on video clips. The pattern of errors, involving a huge proportion of generic verbs (e.g. ''to remove'' versus ''to peel'') relative to responses in control subjects, suggested a hierarchical, bottom-up deficit of action knowledge in SD patients. In addition, abnormal responses in patients consisted of verbs that were semantically related to the expected verbs produced by control subjects (e.g. ''to undress'' versus ''to peel'' for the action [To peel_orange]). This study suggests that, in SD, non-canonical responses to action naming reflect lack of both specificity and semantic relatedness relative to the expected responses.

Learning outcomes: As a result of this activity, readers will recognize that semantic word knowledge disappears in semantic dementia using video clips of object-related actions. As a result of this activity, readers will discover that this semantic impairment followed a hierarchical pattern with the more specific verbs vanishing first.

1. Introduction

Semantic dementia (SD) is a clinical syndrome characterized by a progressive loss of semantic memory/conceptual knowledge that is disproportionate to the decline in other cognitive functions. Such a fundamental breakdown in semantic knowledge was described by Warrington (1975) in her seminal work as a selective deficit of semantic memory and became recognized as a specific clinical syndrome labelled semantic dementia following a report by Snowden, Goulding, and Neary (1989). Bilateral, but usually asymmetric, atrophy of the anterior temporal lobes has been associated with clinical features by

Abbreviation: SD, Semantic dementia.

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Hodges, Patterson, Oxbury, and Funnell (1992). SD is based on an isolated, progressive loss of semantic knowledge, attested by a deficit of word comprehension and a deficit in the identification of objects and/or people. Word finding difficulties are typical in SD, and errors are highly frequent in naming tests and word–image matching tests, due to a huge difficulty in identification resulting from the loss of semantic knowledge (Hodges, Martinos, Woollams, Patterson, & Adlam, 2008; Moreaud et al., 2008; O'Neill, Andreotti, & de Simone, 2006). The preservation of speech fluency and the formal structure of language are in striking contrast to the severity of semantic deficits that induce anomia and verbal paraphasia involving either super-ordinates in a given semantic category or unspecific (Hodges, Graham, & Patterson, 1995; Rohrer et al., 2008; Snowden et al., 2001). Other core features in SD include a perceptual disorder characterized by prosopagnosia, and/or associative visual agnosia. In fact, it has been demonstrated that the key impairment in SD is not simply a word comprehension deficit or a severe naming impairment, but a generalized deterioration of semantic memory that extends across all modalities of input and output, verbal and non-verbal (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000; Hodges et al., 1992; Neary et al., 1998; Snowden et al., 1989). The selectivity of the semantic deficit in these patients is also reinforced by the relative preservation of day-to-day memory and short-term verbal memory, together with good performance on assessments of calculation, visuospatial skills, and non-verbal reasoning. Phonology and syntax, in spite of uninformative spontaneous speech, remain unaffected until very late in the course of the disease (Hodges et al., 1992).

Since SD constitutes a model of progressive and severe degradation of semantic knowledge, it is especially relevant to use language tasks, for instance object naming, and to study the profile of performance in these patients, which may show specific features relative to other degenerative diseases. While impoverished semantic knowledge has been largely documented using object naming tasks, few studies have considered knowledge of object-related actions and the corresponding verbs. Regarding the distinction between nouns and verbs, Bird et al. have stressed that, even though patients with SD "are able to retrieve a sufficient number of verbs to produce sentences, (..) this does not necessarily indicate that verbs are spared relative to nouns" (Bird, Lambon Ralph, Patterson, & Hodges, 2000, p. 20).

Some studies have demonstrated the existence of a deficit affecting action knowledge and verb production in SD. For instance, Bak and Hodges (2003) compared patients with SD, a frontal-variant of Fronto-temporal Dementia (fvFTD), and controls in the "Pyramids and Palm trees test" (PPTT, Howard & Patterson, 1992) and the "Kissing and dancing Test" (KDT), which they constructed by analogy with the PPTT. They compared 52 triplets of actions with 52 triplets of verbs describing them and found that SD patients were impaired on all four subtests (PPTT and KDT word-based and picture-based). SD patients showed greater impairment on the PPTT than on the KDT, but the effect was significant for words only (Bak and Hodges, 2003). More recently, Yi, Moore and Grossman (2007) examined 12 SD patients using a multiple-choice, naming-to-description task, where they had to select the best of four words (nouns and verbs) that matched a verbal description. Participants with SD were significantly more impaired with verbs than with nouns and showed significantly greater difficulty with motion verbs than cognition verbs. Thus, there is growing evidence that SD impacts action semantic knowledge and related verbs as previously documented for objects and nouns (Bird et al., 2000; Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Yi et al., 2007).

In addition, SD does not seem to affect semantic fields uniformly but rather in accordance with their hierarchical structure. In fact, in SD, word retrieval and comprehension deficits are attributed to the erosion of the conceptual knowledge base, or semantic memory that supports language function. As early as her seminal work in 1975, Warrington described the degradation of semantic knowledge as the pruning of the semantic tree put forward by Quillian (Quillian, 1968; Warrington, 1975). The Quillian model proposes a hierarchical organisation of semantic categories within a taxonomic tree, assuming that semantic concepts are organized in a hierarchical structure ascending from the most specific sub-categories at the bottom, to the most general level at the top (Bird et al., 2000; Breedin, Saffran, & Schwartz, 1998; McClelland & Rogers, 2003; Quillian, 1968; Rohrer et al., 2008). The model also specifies that, the more specific an item, the larger the number of semantic features it is associated with. Warrington, then others, have adopted this model to describe a hierarchical (or 'bottom-up') disintegration of semantic knowledge of objects in SD, affecting the most specific nouns earlier and more severely than the most generic ones (Crutch & Warrington, 2007; Hodges et al., 1995; Marques, 2007; Warrington, 1975).

Whether action-related knowledge might be affected according to a similar hierarchical pattern has been addressed only rarely in SD. Such a pattern of bottom-up degradation for action related verbs has been described in other dementias including Alzheimer's disease (Kim & Thompson, 2004), and in aphasia (Breedin et al., 1998). Breedin and Saffran (1999) described the case of an SD patient (DM). Using verb comprehension, they demonstrated that some aspects of verb semantics were impaired in DM. Although this patient retained core aspects of verb meaning (as well as the thematic and grammatical roles of verbs), he was significantly less sensitive to manner features in a set of three specific verbs describing an action performed in different manners (e.g., to crush – to mash – to smear). Such a result is in favour of an advantage of the superordinate level relative to more specific features in verb meaning processing.

In the present study, we first addressed the degradation of action semantic fields in a hierarchical bottom-up fashion, distinguishing generic versus specific verbs in SD patients when compared with healthy participants in an action naming task based on video clips of object-related actions.

Another important aspect of the analysis of lexical semantic impairment in SD relates to the analysis of semantic errors that constitute the majority of incorrect responses. These productions with semantic relatedness to the target (including paraphasias, circumlocutions, and substitutions) suggest incomplete or 'approximate' semantic processing; they are more common in patients than productions involving totally irrelevant semantic information (Jefferies & Lambon Ralph, 2006;

Woollams, Cooper-Pye, Hodges, & Patterson, 2008). This type of production reflects disorders of lexical semantic production and has been largely described in noun lexicon in object naming tasks (Bormann, Kulke, Wallesch, & Blanken, 2008; Hodgson & Lambon Ralph, 2008; Kemmerer & Tranel, 2000; Kim & Thompson, 2004; Meteyard & Patterson, 2009; Woollams et al., 2008).

However, semantic paraphasias and word-finding difficulties may indicate impairment of a number of distinct processes. In this study, we addressed whether these semantically related responses may stand as semantic approximations of the target concept, as responses may represent a 'proxy' item relative to the canonical or expected response. This notion of approximation refers to Jakobson and Halle's work (1956) underlining the importance of semantic proximity in the structure of verb lexicon. This conceptualization has been recently used by Meteyard and Patterson (2009) to refer to anomalous/unclear items used in an event description. This type of semantic paraphasias, which are particularly close to the target, lends support to the idea that the lexicon structure is based on semantic proximity between items rather than on true synonymy. In fact, as proposed by Miller and Fellbaum (1991) "true synonyms are rare, if they exist at all. A weakened version of this definition would make synonymy relative to a context: two expressions are synonymous in a context if the substitution of one for the other does not change the truth value, although there are other contexts where that substitution would be totally inappropriate. Synonymy is simply one end of a continuum on which similarity of meaning can be graded" (p. 202).

In the present work, we investigated whether the error pattern in SD patients performing an action naming task based on video clips was characterized by an increased rate of target-related verbs. These related responses might reflect an adaptive strategy, though not necessarily explicit, to cope with the progressive semantic deficits the patients encounter.

To sum up, the aim of the study was to explore the semantic degradation of action knowledge reflected by verb naming in SD in two ways: (1) a hierarchical description of responses in terms of genericity versus specificity of verbs uttered – in line with previous research on nouns, we expected a hierarchical bottom-up breakdown of action knowledge in SD with a larger proportion of generic items relative to that recorded in healthy subjects; (2) a specific analysis in terms of semantic proximity of the verbs produced, relative to the target.

2. Method

2.1. Participants

All participants were French native speakers. We studied 5 participants affected by semantic dementia (SD) (2 women and 3 men, mean age 68.2 years, sd 5.8, range 69–74) who were selected according to the consensus diagnostic criteria of Neary et al. (1998) and Hodges et al. (1999) by two of us (Dr S. Belliard and Dr O. Moreaud), who are neurologists with considerable expertise in neurodegenerative disorders. At the initial visit, patients underwent a detailed clinical interview, a neurological examination, and an evaluation of mental status. Spontaneous speech was fluent and episodic memory was found to be relatively spared in comparison to the major deficit of semantic memory. The minimental state examination – MMSE (Folstein, Folstein, & McHugh, 1975) was used to assess the level of cognitive impairment and none of the SD patients presented any general impairment (MMSE $>$ 24/30). Laboratory tests and structural brain imaging studies excluded other causes of dementia, such as vascular disease, primary psychiatric disorders, and medical illnesses or metabolic conditions, which could have caused a cognitive deficit. These patients were compared with 17 healthy subjects (13 women, 4 men, mean age 73.2 years, sd 5.2, range 67–83). All subjects of the healthy control group were free of history of neurological disease or injury, psychiatric illness including substance abuse or dependence, and self-reported specific developmental disorders. Both groups were matched for age and education level, the latter being approximately 9 years of full-time education. All healthy participants gave their written informed consent to the study and the testing described below was part of the battery neuropsychological tests that was administered to patients for clinical diagnosis and cognitive assessment purposes.

To describe language abilities and conceptual semantic knowledge in both groups, we report participants' performances in three tests examining word-finding and semantic knowledge: (1) an 80-object–picture naming test in French, DO80 (Deloche & Hannequin, 1997), (2) a 38-action–picture naming test, DVL 38 (Hammelrath, 1999) – these tests were constructed independently and did not present matched sets of nouns and verbs in terms of imageability or frequencies, (3) the picture-based version of the Pyramids and Palm trees test (Howard & Patterson, 1992), which consists of 52 triplets of pictures depicting different objects and can access conceptual knowledge independently of words.

None of the controls had difficulty in performing and completing any part of these tests. The results are shown in Table 1. For the evaluation of individual patients, we defined as normal any score falling within 45/52 on the PPTT (as defined by Howard & Patterson, 1992) and within two standard deviations below the mean provided in the normative data of each test (DO80: 75.7/80, sd 3.2; DVL38: 99.1/114, sd 11.6).

None of the patients had normal results on the three language and semantic tests. The results are shown in Table 1. Table 2 shows the individual results for all the patients. On the object-naming task, all patients were impaired, and two cases showed impairment on the action-naming task. All the patients were impaired on the PPTT, demonstrating that they suffered from core semantic deficits rather than only access difficulty.

Table 1
Performance of the controls and SD patients in the tests.

Tests	Controls		SD patients	
	Mean (SD)	Range	Mean (SD)	Range
MMSE	29.04 (1.33)	25–30	25.08 (0.84)	25–27
DO80 ($n = 80$)	77.8 (1.85)	76–80	49.2 (15.32)	27–64
DVL38 ($n = 114$)	101.3 (9.9)	90–114	78.8 (7.8)	69–84
PPTT pictures ($n = 52$)	51.5 (0.5)	50–52	37.9 (6.6)	27–44

Table 2
Performance of individual SD patients on all four tests.

SD patients	MMSE	DO80	DVL38	PPTT pictures
1	26	27[a]	69[a]	38[a]
2	27	64[a]	80	44[a]
3	25	56[a]	88	38[a]
4	25	40[a]	73[a]	27[a]
5	26	59[a]	84	42.5[a]

[a] Deficient performance when compared to normative data for each test.

2.2. Material and design

We designed an experimental test called "Approx"[1] consisting of 17 video clips of object-centred, everyday human actions and requiring action naming from the subjects. Actions selected to be part of Approx had to be performed with the hands and easily reproducible in a laboratory setting in a limited time (around 1 min). All these actions corresponded to a general type of actions in which an object is either divided into parts or destroyed.

All video clips shared the same general setting: (1) a closed curtain was shown; (2) the curtain rose on a female actor; (3) the woman moved towards a table on which the entire set of objects to be used in the 17 videos was presented. This mode of presentation was intended to avoid priming of a particular semantic domain; (4) the woman performed the target action. These different phases of a video clip [To peel_orange] are presented in Fig. 1.

Normative data were previously obtained for each video clip (Duvignau, Fossard, Gaume, Pimenta, & Elie, 2007) from 60 healthy participants (30 adults: 17 women, 13 men, mean age 30.4 years, range 24–42 and 30 children: 14 girls, 16 boys, mean age 3.5 years, range 2–4.5) who were asked to produce one verb to describe the depicted action. Each video clip was correctly identified by more than 90% of this set of participants. Verbs that were most frequently produced by these participants were considered as referent verbs. The set of 17 videotaped actions and spoken frequencies of the corresponding or referent verbs are presented in Table 3. Frequencies, presented per million of occurrences, were extracted from the French lexical database, Lexique3.55 (New, Pallier, & Matos, 2001). We distinguished two sets of referent verbs according to lexical frequency: the first contained 9 verbs having frequencies higher than 20 (high-frequency group) and the other contained 8 verbs having frequencies lower than 8 (low-frequency group).

2.3. Procedure

A computer screen was placed in front of each participant. After an explanatory phase, each participant was asked to orally name the action in each video clip as soon as the action was completed. The question put to participants at the end of each video clip was: "What did the woman do?" To answer, participants were neither limited in time nor in number of words, although the first action–verb they provided was the only one considered for analysis.

The 17 video clips were presented in random order for each participant and their responses were tape recorded and noted verbatim. The subjects' additional reactions were also noted (e.g. gestures).

2.4. Classification of responses

Previous normative data showed that, from video clips depicting actions in which objects were divided into parts, participants produced about 50 different verbs. Each of these 50 verbs was classified by three independent judges according to three criteria, validity, specificity and expectancy relative to the action depicted in a given video clip. The between-judge agreement rate was above 80%. Any disagreement among judges was resolved by discussion so that a reference verb could be agreed on.

[1] ApproxParadigm, grant from the French National Agency for Research "jeunes chercheurs et jeunes chercheuses", Duvignau, Gaume 2004.

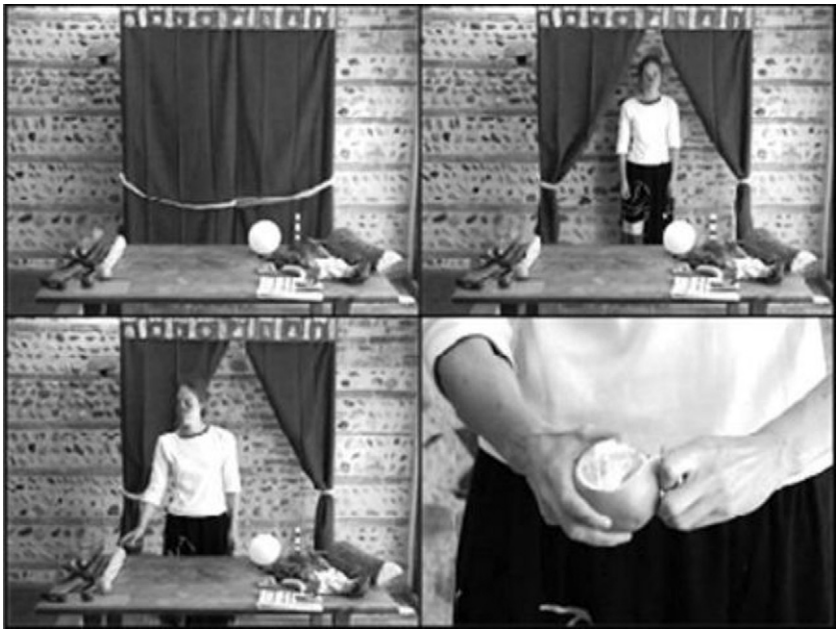

Fig. 1. Phases of a video clip: the curtain is closed, then it rises on a female actor who moves to the table and performs an object-directed action that the participant has to name. Here is the video [To peel_orange].

In the present study, responses produced by healthy participants and patients were classified according to these normative data. Many verbs produced by this normative group were classified by three independent judges, allowing us to rely on a large database of expected and related verbs for each video clip. Each response produced by our participants was either found in this database, or, if not, it was classified by the same three independent judges according to the same procedure.

2.4.1. Validity of responses

The first stage of the coding analysis was to determine whether the verb produced by each participant in each video clip described the action appropriately. If this was not the case, the response was deemed invalid and excluded from further analyses.

Invalid productions were either irrelevant or consisted of gestures to mime the action but no verb production. This analysis led us to eliminate 9 productions across the control group. These participants' invalid responses were either no

Table 3
Set of 17 videotaped actions each defined by the verb produced by healthy adults in a previous normative study. Frequency of occurrence in French for each verb is presented (per million of occurrences).

Videotaped actions	Lexical frequencies of referent verbs
Low-frequency verbs	
émietter_pain/to crumble_bread	0.09
hacher_persil/to chop_parsley	2.18
éplucher_carotte/to peel_carrot	3.27
éplucher_banane/to peel_banana	3.27
éplucher_orange/to peel_orange	3.27
froisser_papier/to crumple_paper	3.74
scier_planche/to saw_board	5.01
démonter_legos/to dismantle_Lego	6.83
High-frequency verbs	
déshabiller_poupée/to undress_doll	22.98
déchirer_journal/to tear_newspaper	26.46
déchirer_chemise/to tear_shirt	26.46
éclater_ballon/to pop_balloon	41.33
écraser_tomate/to squash_tomato	54.42
couper_pain (avec un couteau)/to cut_bread (with a knife)	155.82
couper_pain (avec les mains)/to break bread (with hands)	155.82
casser_verre/to break_glass	160.61
enlever_écorce/to remove_bark	172.47

response (e.g.: "*I don't know*") or a sentence related to the aim of the action (e.g. "*she is going to eat the orange*", failing to describe the action "to peel an orange").

An answer was considered valid if it contained a verb denoting the target-action, no matter how complete the produced utterance (e.g. for the action video [To peel_orange], "pelée"/*peeled* or "peler"/*to peel* were considered valid answers). As noted in Section 1, our theoretical position led us to consider that responses that were different from the typical one (according to our normative database) though semantically related to the target may reflect an adaptive strategy in patients facing failure of semantic knowledge.

2.4.2. Specificity of responses

We distinguished between *generic* verbs that could refer to different tools or target-objects (e.g. *to cut*) and more *specific* verbs that denote additional information about the precise conditions in which the action is performed (e.g. *to saw*, compared with *to cut*, specifies the manner in which the action is performed and also implies a smaller set of possible instruments). Such a distinction relies on the hyperonymy/hyponymy relationship existing between two items in semantic fields.

Thus, a verb was considered specific when: (1) it included in its morphology the name of either the object to which it related or the supposed instrument (e.g. "*to saw*" includes the action instrument "*saw*"); (2) the use of this verb was systematic in the situation considered, or the use of the verb could not extend to other objects (e.g. "*to chop parsley*").

Conversely, the verb "*to cut*" can be applied to all existing objects of the solid dimension in various contexts (e.g. "to cut" for the video *[To chop_parsley]* was generic).

2.4.3. Expected versus related responses

A verb was judged to be expected when its meaning described the action unambiguously (e.g. "to peel an orange" or "to pare an orange" for the action [To peel_orange]). Other valid but less-expected verbal responses were semantically related verbs. Thus, a valid response was classified as related one when it involved a verb that, with regard to the considered action, induced a semantic tension and could therefore be considered odd by the linguistic community. These close-to-the-target semantic paraphasias involve two sub-types:

(1) The 'between-domain related verb'. In this case, the production seemed to be a metaphoric utterance because, in pragmatic terms, the verb did not denote an action that could be combined with the depicted target object (e.g. "*she undressed the orange*" [action video To peel_orange], "*she broke the paper*" [action video To tear_newspaper], "*she peeled the tree*" [action video To bark_log]).

    For instance, in the utterance "*she undressed the orange*" (action video [To peel_orange]), the verb "to undress" was valid because it was semantically related to the target action "to peel" as both verbs shared a common meaning, namely to remove the periphery of an object from its core. In addition we classified "to undress" as a between-domain related verb since it does not denote actions that are conventionally associated with the object category to which the verb/to peel/is related, namely the fruit category.

(2) The 'within-domain related verb'. In this case, the production sounded like a conventional utterance since the denoted action could be combined with the target object (e.g. "*she scratched the orange*" [action video to peel_orange], "*she ground the bread*" [action video To crumble_bread], and "*she folded the paper*" [action video To crumple_piece of paper]). However, the verb was not deemed appropriate to the context as other verbs exist that describe the target action more precisely.

    For instance, in the utterance "*she scratched the orange*" [action video To peel_orange], the verb "to scratch" is valid because it is related to the target action "to peel" and it is congruent with the target object "orange". However, the verb "to scratch" constituted a within-domain related verb since it is not precise enough to describe the target action (as "to peel an orange" would be).

Examples of participants' productions are presented in Table 4.

2.4.4. Frequencies of referent verbs produced by patients

As spoken frequency could influence verb production by participants, we compared frequencies of verbs that patients produced relative to controls, and then we correlated the number of referent verbs that patients were able to produce with the frequencies of these referent verbs, to investigate whether frequencies of referent verbs could predict their production by participants.

3. Results

Before analysis, we excluded the invalid verbs produced by participants from the data set, as described before (see Section 2.4). While SD patients did not provide any invalid verbs, we removed 9 invalid verbs across the control group productions. These invalid verbs were irrelevant to describe the action (e.g. "she is going to eat the banana" for the video [To

Table 4
Examples of SD patient productions and their analysis in terms of specificity and expectancy (actual production in French shown in italics).

Video clip to be described: referent verbs	SD patients' productions	Specificity	Expectancy
To pop a balloon *exploser le ballon*	"To break a balloon" *casser le ballon*	Generic	Between-domain related verb
	"To burst the balloon" *crever le ballon*	Specific	Expected
To peel an orange *éplucher une orange*	"To remove the skin of the orange" *enlever la peau de l'orange*	Generic	Expected
	"To scratch the orange" *gratter l'orange*	Specific	Within-domain related verb
To remove the bark of a log *Enlever l'écorce d'une bûche*	To remove the bark of a log *enlever l'écorce d'une bûche*	Generic	Expected
	"To bark the log" *écorcer la bûche*	Specific	Expected

peel_banana]). Thus the rest of the analyses were based on valid answers only. Verb productions by each participant and medians per group are presented in Table 5 according to the classification criteria described above.

Non-parametric statistical analyses were carried out because of the non-normality of the observed data distribution in small samples of subjects. Mann–Whitney tests were conducted to compare verb production between groups with a Bonferroni correction setting the significance threshold at $p < 0.025$. Two different χ^2 tests were used in each group to explore whether the observed distribution of responses differed from a priori distributions: firstly a comparison between our data and a theoretical distribution of (i) 100% specific verbs (versus 0% generic verbs, and (ii) 100% expected verbs (versus 0% related verbs); secondly, a χ^2 test comparing our data distribution with a random theoretical one (i – 50% specific verbs versus 50% generic; ii – 50% expected verbs versus 50% related verbs).

3.1. Specificity of responses

Controls produced a significantly higher proportion of specific verbs than SD patients ($U(22) = 0, p < 0.0001$). χ^2 tests used to explore the proportion of generic versus specific responses in the two groups showed the following results.

In the control group, the observed distribution differed significantly from the "50% generic–50% specific" theoretical distribution whereas no significant difference was observed for the "100% specific–0% generic" theoretical distribution.

No significant differences were observed for any theoretical distribution in the SD group although a trend ($p = 0.09$) was found for the "100% specific–0% generic" distribution, suggesting a decrease in the rate of specific responses in this group. Results are presented in Fig. 2 and summarized in Table 6.

Table 5
Participants' productions in terms of specificity and expectancy. Median and standard deviations are presented in each group.

Participants	Specificity		Expectancy	
	Generic verbs (%)	Specific verbs (%)	Expected verbs (%)	Related verbs (%)
Controls				
C1	17.65	82.35	82.35	17.65
C2	12.5	87.5	100	0
C3	11.76	88.24	100	0
C4	11.76	88.24	94.12	5.88
C5	11.76	88.24	88.24	11.76
C6	12.5	87.5	87.5	12.5
C7	17.65	82.35	88.24	11.76
C8	5.88	94.1	94.12	5.88
C9	17.65	82.35	82.35	17.65
C10	24.00	76.00	82.35	17.65
C11	11.76	87.5	94.12	5.88
C12	6.25	93.75	100	0
C13	15.38	84.62	100	0
C14	5.88	94.1	100	0
C15	6.67	93.3	100	0
C16	11.76	88.24	94.12	5.88
C17	11.76	88.24	100	0
Median (SD) %	11.76 (4.9)	88.24 (4.9)	94.1 (6.9)	5.9 (6.9)
SD patients				
1	35.29	64.71	70.59	29.41
2	47.06	52.94	76.47	23.53
3	47.06	52.94	76.47	23.53
4	47.06	52.94	82.35	17.65
5	23.53	70.59	82.35	17.65
Median (SD) %	47.1 (10.5)	52.9 (8.3)	76.5 (4.9)	23.5 (4.9)

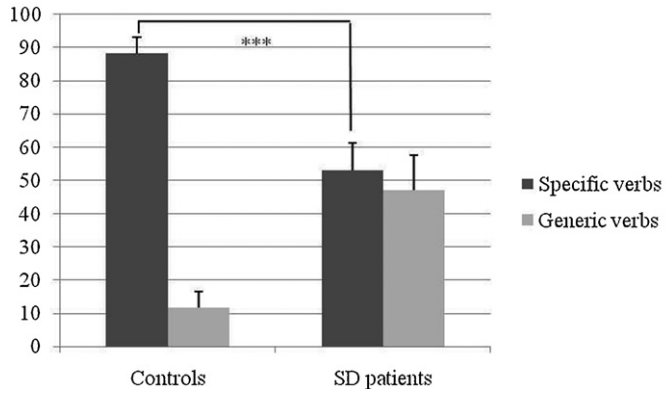

Fig. 2. Medians and standard deviations of verbs produced by participants in terms of specificity. Significant difference of specific verb production between groups is presented (***$p < 0.001$).

Table 6
Participants' production of verbs when compared with theoretical proportions of 100% (vs 0%) and 50% (chance) in terms of specificity and expectancy of verbs produced.

	Median (SD) (%)	χ^2 theoretical 100%	p	χ^2 theoretical 50%	p
Specificity					
SD patients	52.9 (8.3)	2.88	0.09	0.53	0.47
Controls	88.24 (4.9)	0.25	0.62	9	0.003
Expectancy					
SD patients	76.5 (4.9)	0.9	0.33	4.7	0.03
Controls	94.1 (6.9)	0.63	0.8	12.25	0.0005

3.2. Expected versus related verbs

Control participants produced a significantly larger proportion of expected verbs than SD patients ($U(22) = 3$, $p = 0.0005$).

In both groups, the observed proportions differed significantly from the theoretical distribution "50% expected–50% related verbs" whereas no significant difference was observed for the theoretical distribution "100% expected–0% related verbs". Results are presented in Fig. 3 and summarized in Table 6.

Furthermore, we studied the type of semantically related verbs participants produced. As seen before, SD patients produced fewer expected and more related verbs than controls. When patients produced a non-expected verb, it was a

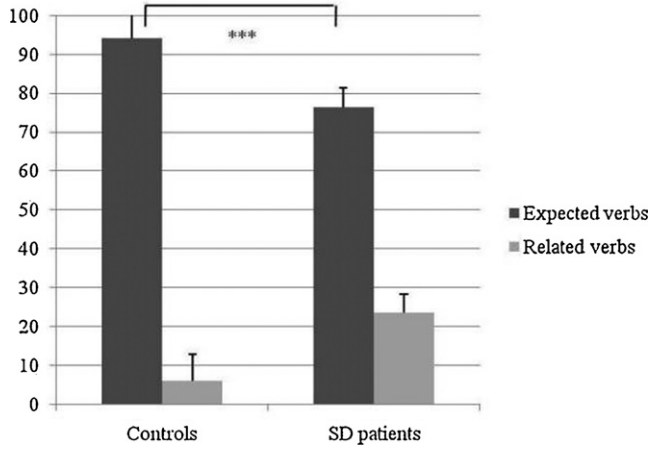

Fig. 3. Medians and standard deviations of verbs produced by participants in terms of expectancy. Significant difference of expected verbs production between groups is presented (***$p < 0.001$).

Table 7
Number of participants who produced the referent verb for each videotaped action, as a function of lexical frequencies of these verbs.

Videotaped actions	Lexical frequencies of referent verbs	Number of participants who produced the referent verb	
		SD patients ($n = 5$)	Controls ($n = 17$)
Low-frequency verbs			
émietter_pain/to crumble_bread	0.09	0	11
hacher_persil/to chop_parsley	2.18	0	14
éplucher_carotte/to peel_carrot	3.27	3	15
éplucher_banane/to peel_banana	3.27	2	13
éplucher_orange/to peel_orange	3.27	2	16
froisser_papier/to crumple_paper	3.74	0	15
scier_planche/to saw_board	5.01	2	16
démonter_legos/to dismantle_lego	6.83	2	7
High-frequency verbs			
déshabiller_poupée/to undress_doll	22.98	4	14
déchirer_journal/to tear_newspaper	26.46	4	17
déchirer_chemise/to tear_shirt	26.46	4	3
éclater_ballon/to pop_balloon	41.33	1	9
écraser_tomate/to squash_tomato	54.42	4	16
couper_pain (avec un couteau)/to cut_bread (with a knife)	155.82	5	10
couper_pain (avec les mains)/to break_bread (with hands)	155.82	4	4
casser_verre/to break_glass	160.61	5	13
enlever_écorce/to remove_bark	172.47	4	7

within-domain related verb most of time. Between-domain related verbs appeared to occur rarely in both control subjects and the SD group. No statistical analysis was conducted on these data because of the small proportion they represented.

3.3. Lexical frequencies of verbs produced

For the "low-frequency set" of verbs, a Mann–Whitney test showed a significant difference between frequencies of verbs produced by SD patients and those produced by controls ($U = 1032$, $p < 0.0001$). Similarly, a significant difference appeared when we compared groups for the frequencies of verbs produced in the "high-frequency set" ($U = 2508$, $p = .01$).

In Table 7, for each item, we present the number of subjects in each group who produced the referent verb in their response. Results could be explained by the fact that SD patients produced many more frequent verbs than control subjects.

SD patients produced a significantly larger number of high-frequency referent verbs than low-frequency referent verbs (Wilcoxon's test, $Z(5) = 2.4$, $p = 0.017$) whereas, in controls, there was no difference between verb sets.

Moreover, patients' responses were directly correlated with the frequency of referent verbs. Actually, the more frequent a referent verb, the more often it was produced by the patients (r^2 ($N = 17$) $= 0.78$; $p = 0.0002$). When patients did not produce the referent verb, they used a more frequent one (e.g. patients produced either "to break" ($f = 160.61$) or "to cut" ($f = 155.82$) for the video [To crumble_bread] ($f = 0.09$); they all produced "to cut" for the video [To chop_parsley] ($f = 2.18$). Conversely, frequencies of referent verbs did not influence control subjects' productions since they produced either the referent verb or a less frequent one (e.g. controls produced either "to unpick", or "to unbutton" for the video [To tear_shirt]).

4. Discussion

The aim of this study was to describe the pattern of verb production during a video-recorded action naming task in SD patients relative to healthy subjects. Verbal productions of participants were investigated according to two approaches in order to improve our understanding of the nature of the semantic deterioration in SD patients and, by extension, contribute to our understanding of its organization. The first was a classical approach assuming a hierarchical organisation of action concepts in terms of genericity versus specificity of verbs produced, likely to reveal a bottom-up degradation of the processing of action verb meanings, as already described for nouns. The second approach aimed to analyse the production of non-expected verbs, re-counting related verbs referring to neighbouring items either within a given semantic domain (within-domain related verb), or between close but distinct semantic domains (between-domain related verb).

Considering the former approach, results showed that SD patients produced significantly more generic and fewer specific verbs than controls, suggesting that the hypothesis of a bottom-up degradation of action semantic knowledge applies to verbs in SD, as previously described for nouns denoting objects.

Considering now the analysis of non-expected verbs produced by participants, results indicated that SD patients produced more related verbs and fewer expected verbs than did healthy subjects. In addition, non-expected utterances were within-domain rather than between-domain related verbs. This result suggests, like the previous one, that although their semantic knowledge became progressively impoverished, these patients still showed preservation of the main semantic boundaries and their responses did not violate semantic coherence between the stimulus and the response they made.

4.1. Degree of specificity and frequency for verbs produced by SD patients

Regarding the semantic breakdown encountered in SD, the description by Warrington as progressive pruning of Quillian's "semantic tree" has been revisited by many authors (Crutch & Warrington, 2007; Hodges et al., 1995; Quillian, 1968; Warrington, 1975). Various studies have proposed that the number of features a concept bears is a significant predictor of decision latencies in tasks involving concrete objects (Cree, McNorgan, & McRae, 2006; Grondin, Lupker, & McRae, 2009; Pexman, Holyk, & Monfils, 2003; Pexman, Lupker, & Hino, 2002). Thus, authors have shown that, in healthy subjects, "increasing the number of shared features [between items] facilitates processing to a greater extent than does increasing the number of distinctive features" (Grondin et al., 2009). Currently, this view of hierarchical nominal lexicon organization and its progressive degradation is widely accepted in SD (McClelland & Rogers, 2003; Patterson, Nestor, & Rogers, 2007; Rohrer et al., 2008) but the organization of semantic knowledge for verbs has only been explored more recently (Silveri, Perri, & Cappa, 2003; Yi et al., 2007). In our study, the relative disadvantage of specific verbs we observed when compared to generic items in SD is in line with the conceptualizations mentioned above: the generic representation of an action concept (with the use of a generic verb like "to take off" for example) would be preserved longer than a specific representation (with the use of a specific verb like "to peel" for example). These findings about verbs concur with observations reported by previous studies regarding knowledge of nouns (Hodges et al., 1995, 1999; Lambon-Ralph, Graham, Patterson, & Hodges, 1999; Lambon-Ralph, Patterson, Garrard, & Hodges, 2003; Rogers & Patterson, 2007). Overall, these results suggest a progressive semantic breakdown in SD, affecting verbs in a hierarchical bottom-up fashion.

Could it be argued that such a profile of semantic impairment is due to a frequency effect? Superordinate items are often the most frequent ones in many languages, including French. Our results in SD patients showed a significant impact of verbs' frequency in their production, since low-frequency referent verbs (e.g. to saw, to peel, etc.) were significantly less often retrieved by patients than were high-frequency referent verbs. Thus, it is probable that these results are in favour of an influence of frequency on patient performance in a verb production task, as previously described for nouns (Bird et al., 2000; Lambon Ralph, Graham, Ellis, & Hodges, 1998).

However, some other neuropsychological studies have described the opposite pattern, such as in agrammatics or aphasia stroke patients, who were impaired at the superordinate level while specific items were spared (Breedin et al., 1998; Thompson, Shapiro, Kiran, & Sobecks, 2003). For instance, Thompson et al. (2003) observed that their agrammatic subjects had more difficulty retrieving verbs associated with more arguments. They hypothesized that this hierarchy effect may relate to the greater processing complexity of verbs bearing numerous arguments; accordingly retrieval of such verbs may require greater processing resources, referred to as the Complexity Hypothesis by Gentner (1981). Nevertheless, in our study, the frequency did not seem to be the only factor influencing verb retrieval since specific though high-frequency verbs were also lacking from patients' productions (e.g. "to pop").

In consequence, the frequency effect alone might not be sufficient to explain the progression of verb-finding difficulty in patients. It is probable that, as for nouns, other factors play an important part in verb retrieval. Concerning nouns, other variables have been proved to impact naming tasks in SD, such as the familiarity of the depicted object and the age at which the majority of people learn its name (Lambon Ralph et al., 1998). Recently, Woollams et al. (2008) showed a pronounced influence in SD of the typicality of a target among other semantically similar items in a very extensive set of object naming data.

It is worth noting that, although previous and the present findings concur to suggest a hierarchical semantic deterioration in SD, it does not necessarily follow that this hierarchy applies to the normal semantic network. In fact, the same pattern could emerge from a damaged distributed feature network. According to this model, knowledge of superordinate items is an emergent property of a distributed network of more distinctive components (McClelland & Rogers, 2003; Plaut & Booth, 2000). The underlying cognitive structure of such a network can thus be reduced to an overlapping organization of discrete feature elements. Higher order knowledge is supported by information that is shared by the members of a given category, whereas exemplar-level knowledge consists of information that is unique to a single member (distinctive attribute). The loss of distinctive attributes therefore causes close concepts to merge. Concepts gradually come to be supported solely by shared properties, thus allowing only category or prototypical representations to emerge. In this case, distributed models such as proposed by McClelland and Rogers (2003) could be applied to action semantic knowledge. According to this model, increases in the degree of perturbation, as in SD, would degrade the network's ability, first to activate specific information about the concept (specific verb, action-specific properties) and later to activate more general properties. In consequence, shared properties tend to be preserved whereas idiosyncratic ones tend to be lost, and properties that a concept does not share with other similar concepts tend to come back as the representations become less differentiated.

Based on this view of semantic knowledge becoming less and less differentiated in SD, it seems to be of major importance to consider unexpected but semantically related utterances in an action naming task as hints revealing more about action-concept degradation than the mere classification between expected versus erroneous responses. While most research considers the latter as a homogeneous set of ''semantic errors'', in the present study we propose that some of these productions could be seen as reflecting the progressive loss of limits between close semantic domains. This is why we have focused on non-expected verbs and distinguished within- and between-domain semantically related verbs.

4.2. Analysis of non-expected utterances in SD group

This study focused on a new approach to participants' productions in an action naming task, considering expected as well as non-expected utterances. There is a long tradition of using naturally occurring speech errors to inform models of language production, under the assumption that such errors are constrained by components of linguistic processing (Cutler, 1981; Fromkin, 1971). In their recent analysis of a large corpus of SD naming errors, Woollams et al. (2008) indicated that responses denoting retrieval of either insufficient information (omissions) or partial/approximate knowledge (semantic errors, superordinate responses, informative circumlocutions) were far more common in SD patients' productions than those containing incorrect or inappropriate semantic information (unrelated errors, other circumlocutions, other errors). In picture-naming tasks, it has been shown that patients with SD produce many coordinate and superordinate errors but virtually no associative errors (Jefferies & Lambon Ralph, 2006). For low-frequency atypical items, it has been proposed that regularization errors occur because domain-specific representations are insufficient to generate the correct response in the absence of support from semantic memory (Patterson et al., 2006). Many studies confirm previous evidence of SD patients' problems with open class content words which are replaced by higher frequency, less specific terms. Such semantic ''errors'' would be in keeping with the specific-to-general pattern of degradation observed in previous studies (Hodges et al., 1995; Rogers et al., 2004; Warrington, 1975) and confirmed by our results about verb production. However, we propose that some of these semantic errors affecting verbs, which we label semantically related verbs, could reflect another specificity of degradation of action semantic knowledge.

As mentioned by Meteyard and Patterson (2009), the majority of anomalous utterances found in SD patients' productions were not frank syntactic violations but rather semantically deviant responses because of an infelicitous choice of items to express a given meaning. We think these utterances do not consist of an ''infelicitous choice'' but rather of adaptive, though not necessarily explicit, strategies to cope with the progressive semantic deficits SD patients encounter. Therefore, these deviant responses should be fully taken into consideration when describing action semantic knowledge degradation. Our results confirm that SD patients produce a higher proportion of semantically related verbs in comparison with control subjects. Instead of being erratic and inappropriate to describe the action of the video clip, these related verbs suggest that, even though an action semantic domain is partly degraded, patients are still able to select a verb that could describe the depicted action. This consideration is in line with the proposal of Cree and McRae (2003) about concrete nouns that items pertaining to the same semantic domain are closer than items pertaining to distinct semantic domains. These authors suggest that certain categories would show many occurrences of overlapping, which could be a predominant factor in semantic knowledge degradation because concepts that are semantically very similar would tend to be particularly confounding. Consequently, the density of the semantic neighbourhood would be an important factor when performance on semantic tasks is analysed in SD patients.

Nevertheless, our results showed that patients did not produce between-domain related verbs but rather within-domain ones. This finding might be interpreted either as the mildest effect of the progressive impoverishment of semantic knowledge or as an attempt to compensate failure to retrieve the target response. The former interpretation is in keeping with the relationship that seems to exist overall between semantic deficit and related verb production. However, the absence of between-domain related verbs might also be linked to the fact that SD patients suffer from too severe a deficit to be able to retrieve the most specific representative verbs whatever the semantic sub-domains considered. In other words, the pathological and profound pruning of the semantic tree might preclude the observation of specific, between-domain related verbs. Further studies would need to use follow-up to explore the significance of these particular non-expected utterances in both the verb and the noun domains and the relationships between the fine-grained production profile and disorders of semantic comprehension.

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Appendix A. Continuing education

1. What is a semantic approximation?
   (a) A valid answer
   (b) An invalid answer
   (c) A valid and unconventional answer
   (d) An invalid and unconventional answer
2. Which task has been used to explore semantic approximations in participants?
   (a) A picture-based action naming task
   (b) A picture-based object naming task
   (c) A video-based action naming task
   (d) A video-based object naming task
3. In this study, a hierarchical bottom-up breakdown has been revealed concerning:
   (a) Verbs in patients affected by semantic dementia
   (b) Nouns in patients affected by semantic dementia
   (c) Both nouns and verbs in patients affected by semantic dementia
   (d) Neither nouns nor verbs in patients affected by semantic dementia
4. Patients affected by semantic dementia produced:
   (a) More generic and fewer specific verbs than controls
   (b) More specific and fewer generic verbs than controls
   (c) As much generic and specific verbs as controls
5. Patients affected by semantic dementia produced:
   (a) More expected verbs than controls
   (b) More related verbs than controls
   (c) As much expected and related verbs as controls

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