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DAILY LIFE ACTIVITIES IN PATIENTS WITH ALZHEIMER'S DISEASE OR SEMANTIC DEMENTIA: MULTITASKING ASSESSMENT

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Highlights:

- Multitasking impairment occurs early in Alzheimer's disease and semantic dementia.
- New tasks and measurements are needed to explore everyday action impairment.
- Patients with these diseases show perplexity, exploring objects but not using them.
- These patients exhibit varying sensitivity to distractor items and task conditions.

Abbreviations: AD = Alzheimer's disease; ANCOVA = analysis of covariance; ANOVA = analysis of variance; BADL = Basic Activities of Daily Living; BEC 96 = Batterie d'Evaluation Cognitive 96; FACA = Functional Association and Categorical Association; IADL = Instrumental Activities of Daily Living; MLAT = Multi-Level Action Test; MMSE = Mini-Mental State Examination; NAT = Naturalistic Action Test; SD = semantic dementia; SDLM = Sequential Daily Life Multitasking; SET = Six Elements Tests; ToL = Tower of London.

ABSTRACT

The aim of the present study was to compare patients with mild to moderate Alzheimer's disease (AD) or semantic dementia (SD) on their cognitive processes and the severity of their daily life activity impairments. Three types of tasks were administered to patients (SD = 15; AD = 31) and 30 healthy controls (HC): 1) informant-based scales and questionnaires, 2) a neuropsychological assessment exploring executive functions, episodic and semantic memory, and 3) a new original test featuring multi-step naturalistic actions and multitasking: the Sequential Daily Life Multitasking (SDLM). We predicted that patients with AD would mainly exhibit task perplexity, associated with episodic and executive deficits on the SDLM, while the behavior of patients with SD would mostly be characterized by object perplexity, associated with semantic memory deficits. Results showed that patients with AD or SD were impaired across all neuropsychological tests, particularly episodic memory in AD and semantic memory in SD. General performance on the SDLM also appeared dramatically impaired in both patient groups, and correlated with results of questionnaires about instrumental activities and memory impairments. However, specific qualitative measurements on the SDLM did not allow us to pinpoint different patterns of errors and behavior in patients with AD versus SD. We suggest that the inability of patients in both groups to perform the SDLM may derive from a constellation of disorders or else from more subtle impairment of cognitive and conative processes that requires further exploration.

1 Introduction

Assessment of everyday action in dementia is crucial to ensure accurate early diagnostic classification, test interventions, and evaluate disease progression (Patterson et al., 1992; Bucks et al., 1996; Giovannetti et al., 2008, 2012; Garrido-Pedrosa et al., 2017). Unfortunately, compared with other cognitive domains affected by dementia, such as memory and language, everyday actions have been poorly investigated, and disorders have long been described solely in generic terms, using informant-based instruments such as scales or questionnaires, with a clear lack of theoretical perspectives. Furthermore, patient samples are frequently diverse, and sometimes heterogeneous (Giovannetti et al., 2012, 2013). Experimental results suggest that caution is needed when extrapolating everyday functioning from classic assessments of cognitive functions or informant-based questionnaires (Giovannetti et al., 2002; Royall et al., 2007; Piquard et al., 2010; Martyr and Clare, 2012), as specific kinds of errors are linked to specific kinds of neurodegenerative diseases (Giovannetti et al., 2002, 2006, 2013, 2015; Mioshi et al., 2007; Okazaki et al., 2009; Cornelis et al., 2017).

One of the first studies to examine daily life activities in dementia in detail was Buxbaum et al. (1997)'s set of two case studies. Despite moderate to severe loss of functional and associative object knowledge, DM, a patient with SD, performed almost normally on executive functions, single-object use, and the Multi-Level Action Test (MLAT). By contrast, HB, a patient with very probable AD, made numerous errors on the MLAT (e.g., step omission, action addition, mis-selection and misuse of objects), and exhibited a deterioration in episodic memory and executive functions, but preserved single object use and semantic memory. This comparative work provides a good model for exploring cognitive processes involved in daily life activities, as AD and SD are both neurodegenerative diseases in which brain damage initially appears to take place in cortical, particularly temporal, regions with the basal ganglia remaining unaffected. Thus, cognitive deficits first concern memory (episodic and semantic) and executive functions, while behavior and motor functions are initially preserved. SD is of particular interest when exploring the role of semantic knowledge in object use, and thus in everyday actions. The preservation of everyday action in SD is still matter of debate. Funnell (2001)' review underlined the ability of patients with SD to select and use familiar or novel tools appropriately, or to perform naturalistic actions. However, in Mioshi et al. (2007)'s group study, patients with AD were intermediately affected, while those with SD were less impaired but not completely spared in instrumental activities.

Giovannetti and colleagues (2002, 2006, 2007, 2008, 2012) conducted a long series of studies in the wake of Buxbaum et al. (1997). These authors explored everyday activities with the Naturalistic Action Test (NAT), a shortened version of the MLAT (Schwartz et al., 2002) that features three everyday tasks of increasing complexity: making toast, wrapping a gift, and packing a lunch box. Tasks are performed one after the other, in the presence of specific distractor objects. Participants are given clear instructions and goals. A quantitative accomplishment score is calculated, and a qualitative detailed error analysis is also performed according to a model that distinguishes between two general types of errors: omission (of tasks), and commission (substitution, addition, perseveration, sequence, etc.). NAT's validity has been confirmed by significant correlations between the results of an informant-based questionnaire (Instrumental Activities of Daily Living, IADL; Lawton and Brody, 1969) and task scores (accomplishment score and total errors). Giovannetti et al. (2008, 2012) confirmed the validity of the omission-commission model in dementia, showing that omission errors (predicted by measurements of episodic memory) are more present in patients with cortical neurodegenerative diseases such as AD, whereas commission errors (predicted by measures of executive function) are more present in patients with subcortical neurodegenerative diseases such as Parkinson's disease or vascular dementia. In a recent study, Roll et al. (2019) specified that semantic difficulties, which are frequently reported in AD, are observed early and contribute to functional difficulties. There have been numerous studies of everyday functioning in dementia, among either heterogeneous populations or exclusively participants with AD. However, although some investigations have been carried out among individuals with mild cognitive impairments, vascular dementia or Parkinson's disease, little is known about SD, despite the presence of more severe semantic deficits than in AD and specific tool use deficits, depending on context, tool familiarity, or goal identification (Hodges et al., 1992, 2000; Snowden et al., 1994; Buxbaum et al., 1997; Lauro-Grotto et al., 1997).

Giovannetti et al. (2013) rightly pointed out the need to develop specific tools and measurement techniques, such as the timing and taxonomy of errors, and called for a process approach to be incorporated into everyday action assessments in clinical and experimental neuropsychology. The NAT (Schwartz et al., 2002) is commonly used to explore sequential, multi-step or naturalistic action in dementia. However, unlike the MLAT (Buxbaum et al., 1997), it is said not to require multitasking (Seligman-Rycroft et al., 2017). According to Burgess (2000a), *multitasking* is a common characteristic of most daily life activities, and relates to situations involving several tasks of varying difficulty or priority. Performances on these tasks need to be dovetailed, if they are to be time-effective, but only one task can be performed at any one time. Targets are self-determined (open-ended), and there is no immediate feedback about time or performance. Many daily life activities involve one or more of these characteristics, and we suggest that the NAT also includes some of these features, such as tasks of varying difficulty or no immediate feedback. However, unlike for the classic Six Elements Tests (SET; Shallice and Burgess, 1991; Burgess 2000b), targets on NAT are not self-determined, and performances on each task do not need to be dovetailed.

1.1 Aim of the present study

The aim of this study was twofold: 1) objectify and compare the severity of everyday action impairments in mild to moderate AD versus SD, using Sequential Daily Life Multitasking (SDLM), a new and original test developed by our laboratory, featuring multi-step naturalistic actions and multitasking; and 2) highlight the underlying cognitive processes and variables elicited by the SDLM, and identify the ones that are specific to each group of patients (AD and SD). The assessment protocol revolved around the three main principles identified in the literature: 1) informant-based scales; 2) cognitive tasks examining global cognitive impairments, executive control, episodic memory, and semantic memory; and 3) specific quantitative and qualitative assessments of daily life activities via the SDLM. To control for the effect of distractor objects and conjunction of tasks (Buxbaum et al., 1997; Shallice and Burgess, 1991), tasks were performed in two conditions: choice and no-choice. Overall quantitative performances were explored via accomplishment scores for each condition. Inspired by the SET (Shallice and Burgess, 1991), we also devised a task-switching measure to explore goal maintenance and executive control deficits. Three time measurements were also taken into account for the qualitative analyses: inappropriate use, exploration, and doing nothing. These four measurements were originally intended to serve as cognitive indicators, picking up micro-errors in order to examine error-monitoring abilities and quantify inefficient but not overtly erroneous task execution in healthy young and older adults, as well as patients with mild cognitive impairment or dementia (Balouch and Rusted, 2013, 2014; Seligman et al., 2014; Seligman-Rycroft et al., 2017). Micro-errors are known to be sensitive to increasing task demands, as in multitasking and dual task conditions. They are also known to reflect the early stages of cognitive decline (Rycroft et al., 2018). Moreover, micro-errors have been shown to be correlated with neuropsychological measurements of episodic memory (Seligman et al., 2014).

1.2 Predictions

Following the recent extension of the omission-commission model (Roll et al., 2019) and previous theoretical suggestions about tool use, we set out to analyze the behaviors and error patterns of patients with SD and AD on the SDLM, using a model that distinguishes between object and task perplexity. Initially described in patients with left-brain damage, perplexity can be defined as any action that does not involve the appropriate interaction between a tool and an object, such as either doing nothing, or exploring or handling a tool or object in isolation (De Renzi and Luchelli, 1988; Osiurak et al., 2013; Lesourd et al., 2015). In relation to semantic memory deficits, *object perplexity* characterizes the omission or substitution of objects, the inappropriate selection, use or association of objects, and mis-identification of object functions, particularly when distractor items are present. In relation to deficits in episodic memory and executive functions, *task perplexity* characterizes the misidentification of task goals, the premature termination of tasks, omissions of steps, perseverative errors, and even a lack of initiative, particularly when goals and contexts are ambiguous, such as in task conjunction. We therefore tested several predictions: 1) patients with SD would be less impaired than patients with AD, but not completely spared, on the SDLM in the no-choice condition and informant-based assessment of everyday functioning; 2) SDLM performances in the choice condition would be particularly disturbed in both groups of patients, and associated with semantic memory impairments in SD and episodic-executive impairments in AD; 3) as a result of episodic and executive deficits entailing task perplexity, patients with AD would spent more time doing nothing, and demonstrate more task switching, while inappropriate use and exploration times would be longer for patients with SD, as a result of semantic memory deficits entailing object perplexity.

2 Participants and Methods

2.1 Participants

Two groups of right-handed participants were recruited from four neurology units in France: 31 patients with AD, and 15 patients with SD. All cases were diagnosed by an experienced neurologist, in accordance with standard and international consensus criteria. Patients with AD fulfilled the criteria for the diagnosis of probable AD (McKhann et al., 2011). The clinical diagnosis of SD was based on the progressive loss of the meanings of words, objects and/or faces in the context of relatively spared episodic memory, perceptual and language abilities (Neary et al., 1998; Gorno-Tempini et al., 2011). All patients underwent a neurological examination to rule out sensory, vestibular, cerebellar, pyramidal or Parkinsonian syndrome, together with an MRI scan in the course of the standard diagnostic procedure. They were excluded if there was evidence of major cerebrovascular disease. Patients with AD were included when imaging revealed hippocampal atrophy with or without background cerebral atrophy, and patients with SD were included if they had cortical atrophy and/or hypoperfusion restricted to (or at least predominant in) the temporal polar regions. A total of 31 healthy controls (HC) were recruited either in senior clubs or through a clinical research center. All participants lived at home and had no previous history of neurological or psychiatric illness. As is typical for these etiologies, the patients with AD were older than those with SD. Moreover, the patients with SD had a higher education level (AD = 8.7 years; SD = 11.9 years; $p < .05$; see Table 2). The HC group was matched with the AD group on age, and with the SD group on education (see Table 2). These are well known methodological issues that reflect a clinical reality (e.g., Hodges et al., 1992; Snowden et al., 2001). To overcome these biases, age and education level were introduced as covariates in the quantitative analyses. For the sake of future meta-analyses, it should be noted that all the participants here (patients and controls) had already been included in previous studies (Baumard et al., 2016, 2018, 2019; Lesourd et al., 2016, 2017).

The study was conducted in accordance with the Declaration of Helsinki and approved by a local ethics committee and the local health authorities (Western Protection to Persons Committee II, no. 2012/32). Informed consent was obtained for all participants.

Table 1
Means, standard deviations, and statistical comparisons of demographic variables.

	HC (n = 30)		AD (n = 31)		SD (n = 15)		ANOVA*		
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Post hoc comparisons
Age (years)	75.83	6.44	76.77	7.25	67.20	7.62	10.30	< .001	SD < (HC = AD)
Education (years)	12.23	4.75	8.74	4.19	11.86	2.74	5.87	.004	AD < (HC = SD)
Sex **: women/men	20/10		22/9		8/7		*ns***		

Note. HC: healthy controls; AD: patients with Alzheimer's disease; SD: patients with semantic dementia; ANOVA: analysis of variance. * *df* = 2.73. ** Gender analysis performed with chi2 analyses.

2.2 Experimental protocol

2.2.1 Informant-based questionnaires

Patients' caregivers were asked to complete French versions (Israël and Waintraub, 1986) of two classic scales usually used in centers for memory assessment and recommended by the French Health Authority (HAS, 2015): Basic Activities of Daily Living (BADL; Katz et al., 1963), and Instrumental Activities of Daily Living (IADL; Lawton and Brody, 1969). The BADL scale is composed of six items concerning basic activities (e.g., bathing, toileting or locomotion). The nine items of the version of the IADL scale we used cover more complex activities, such as using a phone and handling finances. Each item in each scale is rated on a 4-point scale ranging from 0 (*Total autonomy*) to 3 (*Complete dependency*) (maximum score = 18 for BADL and 27 for IADL). Lower scores on the BADL and IADL reflect greater independence in daily activities.

2.2.2 Neuropsychological assessment

All patients were first examined using the Mini-Mental State Examination (MMSE; Folstein et al., 1975) and a French neuropsychological global cognitive battery: Batterie d'Evaluation Cognitive 96 (BEC 96; Signoret et al., 1989; see Lesourd et al., 2016, for a detailed description). The BEC 96 comprises eight subtests designed to assess memory, executive and verbal abilities: Orientation, Verbal learning, Visual recognition, Mental manipulation, Abstract reasoning, Categorical fluency, Naming, and Visuoconstructive skills. All subtests are rated on a 12-point scale. The maximum score is 96 (i.e., sum of the eight subtests). In the present study, we also calculated two specific scores: episodic score (/24; Verbal learning + Visual recognition), and executive score (/36; Mental manipulation + Abstract reasoning + Categorical fluency). Executive functions were also tested through a modified version of the classic Tower of London (ToL; Shallice, 1982). There were two examples and six problems that ranged from two to seven moves (Berg and Byrd, 2002). The time limit was set at 2 minutes for each item. Performance was rated on a 4-point scale (see Jarry et al., 2013, for details), depending on the number of moves (maximum score = 18). We also recorded the mean time for successful items.

Concerning semantic memory for action, we administered two tests to assess tool knowledge (Baumard et al., 2016). Each test comprised two corrected practice items and 10 items, where four images of objects were displayed below the picture of a tool. Participants were asked to select the object that best matched the target tool. For Functional Association (FA), the criterion was the function of the tool (e.g., target = match; choice = *lighter*, pen, coffee maker, colander). For Contextual Association (CA), the criterion was its usual context of use (e.g., target = match; choice = *birthday*, wedding, Christmas Day, baptism). For each test, a score of 1 point was awarded if the correct answer was given within 30 seconds, with a total possible combined score of 20 (FA + CA). We also recorded the mean time for successful items across the two tests.

2.2.3 Sequential Daily Life Multitasking

Everyday actions were assessed using a novel experimental tool inspired by Buxbaum et al. (1997), Giovannetti and colleagues (Giovannetti et al., 2002, 2006, 2008) and the SET (Shallice and Burgess, 1991). In this test, participants were asked to complete a series of three multi-step, sequential tasks: 1) making coffee with an electric coffee maker (bottle of water, coffee machine, coffee filters, coffee pot, measuring spoon); 2) preparing a synthetic floral decoration (vase, plastic flowers, plastic reeds, floral foam, pot pourri); and 3) repairing a flashlight (flashlight, light bulb, battery). In the choice condition, all the equipment required for the three tasks was simultaneously placed on the table, so that the tasks could be performed in conjunction with each other in an unconstrained order, with the objects of each task constituting distractor items for the other two tasks. The placement of the objects was standardized (see Fig. 1). Instructions were deliberately open-ended, so as to reflect the everyday ecological context better (Burgess, 2000a, 2000b): “I will ask you to perform several activities, using the objects placed in front of you.” We deliberately avoided informing participants about the goals and the number of tasks, but the examiner initiated the first action by pouring water in the coffeemaker’s water tank and saying, "Go ahead, go on, do what there is to do." Participants’ performance was videotaped for later scoring, and we recorded completion times. Scoring took into account the final outcome of actions when participants spontaneously indicated that they had completed all the tasks. The time limit for completing the three tasks was 4 minutes and 30 seconds. We calculated an accomplishment score based on an evaluation grid, taking into account the number of central actions correctly performed for each task (see Table 2). The maximum SDLM accomplishment score in the choice condition was 16. Inspired by the SET, the number of times participants started another task before they had completed the current one was also counted as objective planning and/or goal maintenance difficulties (SDLM task switching).

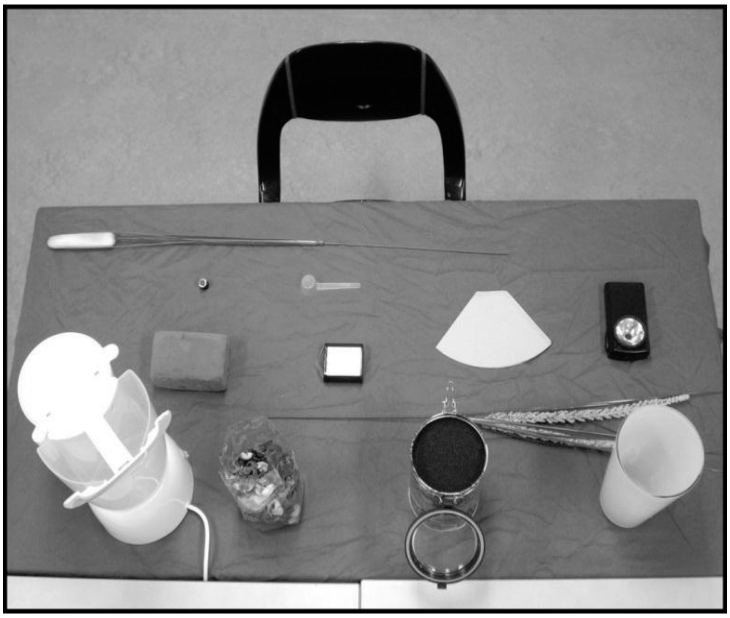


Figure 1. SDLM. Material for the choice condition.

Table 2
Quantitative rating criteria for SDLM.

Tick the box when the action is fulfilled:	
Making coffee	**/ 6**
Filter is properly positioned	
Coffee powder is poured in using measuring spoon	
Coffee powder is in the filter	
Filter compartment is closed with coffee inside	
Glass coffee pot is properly positioned	
Coffee maker is switched on	
Flashlight	**/4**
Bulb is well positioned	
Battery is well positioned	
Lamp housing is closed	
Lamp is switched on	
Floral decoration	**/ 6**
Floral foam is in the vase	
First flower is inserted into the floral foam	
Second flower is inserted into the floral foam	
Plastic flower is in the vase with or without floral foam	
Plastic reed is in the vase with or without floral foam	
Pot pourri is in the vase	
SDLM Accomplishment score:	**/16**

For the no-choice condition, we only placed the material needed for one task at a time on the table. Its placement was also standardized (see Fig. 2). For each task, the examiner gave the following instruction: "Using the objects in front of you, I will ask you to do what has to be done." The time limit is set at 1 minute and 30 seconds. We deliberately did not verbalize the purpose of the tasks. Scores for each task were calculated and summed. Completion times were recorded. As in the choice condition, the maximum SDLM accomplishment score in the no-choice condition was 16.

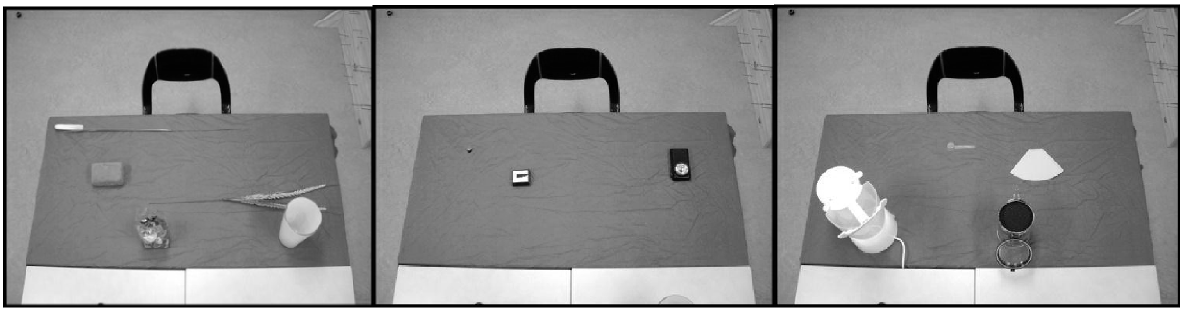


Fig. 2. SDLM. Material for the no-choice condition.

2.2.4 Additional time-based scoring system

To overcome problems such as ceiling effects in healthy controls and score distribution, we adopted an original three-step scoring procedure for the SDLM in the no-choice condition: 1) completion times were collected for every item where participants achieved the maximum score (6 for making coffee, 4 for flashlight, and 6 for floral decoration); 2) the 5th, 25th, 75th and 95th percentile ranks were calculated for completion times for each item in the control group; and 3) additional points were given to items according to their completion time, such that if the item completion time was below C5, 7 points were granted, if the completion time was between C5 and C25, 5 points were granted, if the completion time was between C25 and C75, 3 points were granted, and if the completion time was between C75 and C95, 1 point was granted. For completion times above C95, 0 points were granted (e.g. if Item AS1 was perfectly performed with a score of 6/6 and a completion time between C5 and C25, it was given five more points; 6 + 5 = 11). The aim of this method was to create a composite, time-based, score that took performance and completion time into account. This procedure had previously been tested and validated in other studies of mechanical problem solving (for more details, see Baumard et al., 2016, 2018; Lesourd et al., 2016, 2017). The maximum SDLM time-based score in the no-choice condition was 37.

2.2.5 Additional specific time measurements for SDLM in choice condition

In addition to the scores set out above, we took four time measurements into account in the SDLM choice condition:

-Total time: time taken by participants to satisfactorily complete the three tasks;

- Inappropriate use time: time during which participants tried to use inappropriate combinations of items (e.g., using measuring spoon with light bulb). In line with object perplexity, this could correspond to substitution errors;

- Exploration time: time during which participants handled and examined a single object without doing anything else. In line with object perplexity, this could refer to the misidentification of object functions;

-Time spent doing nothing: time that participants spent doing nothing at all. In line with task perplexity, this measurement served to explore more particularly participants' lack of initiative and misidentification of the task goals or sequence.

2.3 Statistical analysis

Statistics were conducted using the R multcomp package (Hothorn et al., 2008). Given that the experimental groups were not matched on age and education (Table 1), we used analyses of covariance (ANCOVAs), controlling for age and education, to examine the effect of group (HC, AD, SD) on neuropsychological tests, caregiver reports, and SDLM scores. One-way ANCOVAs with Tukey's correction were used for post hoc between-group comparisons. For the SDLM, we also ran a two-way ANOVA with the between-participants factor group (AD, SD) and the within-participants factor condition (choice vs. no-choice). Effect sizes for within-group differences were estimated using Cohen's *d* (.2 = small; .5 = medium; .8 = large). Relations between SDLM measurements ($n = 7$) and neuropsychological variables ($n = 7$) were assessed using bivariate correlations ($n = 49$), with Bonferroni's correction to avoid Type I errors (.05/49). We only considered correlations with *p* values < .001.

3 Results

3.1 Everyday functioning and neuropsychological characterization of the groups

Some data were missing (see Table 3), as patients' impaired comprehension or slowness meant that some tests could not be completed and scored (e.g., too many verbal subtests/items). Sometimes, length of hospital for patients stay was insufficient to conduct the experimental testing. Concerning the BADL and IADL, some data were missing because of a complex hospitalization context or difficulty meeting the patients' relatives. As shown in Table 3, patients with SD ($M = 24.18$) performed better on the MMSE than patients with AD did ($M = 20.19$, Tukey = 3.87; $p < .001$), but we did not find any difference between patients with AD versus SD on overall autonomy, which was moderately affected according to the IADL. Both dementia groups had a low global cognitive score on the BEC 96. Considering more specific functions, patients with AD ($M = 12.03$) exhibited greater impairment than those with SD ($M = 15.91$) on the episodic score (Tukey = 2.56; $p = .032$), while the SD group ($M = 24.73$) displayed a greater deficit than the AD group ($M = 29.52$) on the executive score (Tukey = -2.70; $p = .022$). ToL performance was significantly impaired, but only for patients with AD (HC vs. AD post hoc: Tukey = 3.74*;* $p = .001$), who were also significantly slower than HC (HC vs. AD post hoc: Tukey = -2.61; $p = .029$). Both dementia groups had a lower FACA score than controls, but patients with SD had a significantly longer FACA time (SD vs. AD: Tukey = 3.16; $p = .006$).

Table 3
Means, standard deviations, and statistical comparisons for demographic variables.

	No. of participants	Min-Max*	HC (n = 30)		AD (n = 31)		SD (n = 15)		ANCOVA Controlling for age and education			Post hoc comparisons
			M	*SD*	*M*	*SD*	*M*	*SD*	*df****	*F*	*p*	
BADL	39	0-18	NE**		1.75[a]	1.94	1.27[e]	1.56	1, 35	0.52	0.47	AD = SD
IADL	40	0-27	NE**		11.10[b]	6.07	8.64[d]	8.48	1, 36	0.47	0.49	AD = SD
MMSE	72	0-30	27.20	1.75	20.19	2.80	24.18[e]	3.46	2, 66	52.50	< .001	HC > SD > AD
BEC 96	72	0-96	88.05	4.66	67.24	9.18	66.55[f]	11.83	2, 66	54.74	< .001	HC > (AD = SD)
Episodic score (BEC 96)	72	0-24	21.60	1.87	12.03	3.17	15.91[f]	4.11	2, 66	71.16	< .001	HC > SD > AD
Executive score (BEC 96)	72	0-36	32.70	2.26	29.52	5.40	24.73[f]	4.27	2, 66	10.61	< .001	HC > AD > SD
ToL	76	0-18	14.17	1.46	10.61	3.32	12.33	5.25	2, 70	7.22	< .01	AD < (HC = SD)
ToL time	76	0-120”	27.97	9.29	36.08	12.82	31.58	10.67	2, 70	3.41	< .05	AD > C; AD=SD; C=SD
FACA	76	0-20	18.40	1.45	15.19	3.25	13.60	4.76	2, 70	12.88	< .001	HC > (AD = SD)
FACA time	76	0-30”	5.42	1.66	7.74	2.93	10.82	4.68	2, 70	15.66	< .001	SD > AD > HC

Note. HC: healthy controls; AD: Alzheimer’s disease; SD: semantic dementia; BADL: Basic Activities of Daily Living; IADL: Instrumental Activities of Daily Living; MMSE: Mini-Mental State Examination; BEC: Battery of Cognitive Efficiency; ToL: Tower of London; FACA: Functional Associations and Categorical Associations. * Higher scores reflect better performances, except for BADL, IADL, ToL time and FACA time. **NE: not examined.

3.2 SDLM: choice and no-choice conditions

Table 4 sets out the overall and specific SDLM measurements. According to the ANCOVA controlling for age and education, general performances (accomplishment score) were significantly impaired in both patient groups (AD and SD), irrespective of condition (choice or no-choice; all *p*s < .001). However, as shown in Figure 3, the SDLM accomplishment score generated strong ceiling effects, and scores were clearly not normally distributed in the HC group ($W = .76$, $p < .001$). To confirm task sensitivity, we adopted an additional scoring procedure based on completion times in the no-choice condition: the SDLM time-based score (see Section 2.2.4). After data transformation, the scores were normally distributed in both the HC group (SDLM time-based score for HC: $W = .96$, $p = .30$) and the two patient groups (SDLM time-based score for AD: $W = .96$, $p = .37$; for SD: $W = .96$, $p = .72$).

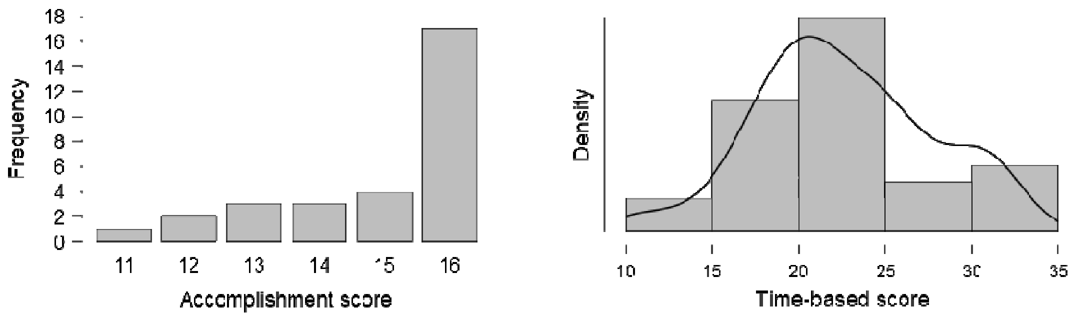


Fig. 3. Healthy controls: Frequency distribution of SDLM scores in the no-choice condition, obtained using two different scoring systems: accomplishment score (range: 0-16) and time-based score (range: 0-37).

The ANCOVA conducted on the SDLM time-based score confirmed the significant main effect of group, $F(2, 70) = 25.21$, $p < .001$. The post hoc Tukey test with Bonferroni correction showed that HC ($M = 22.60$) performed better than patients with either AD ($M = 12.03$, Tukey: 6.42; $p < .001$) or SD ($M = 13.80$, Tukey: 4.99; $p < .001$). There was no difference between the two patient groups (Tukey: -0.15; $p = 0.987$).

Table 4
Means, standard deviations, and statistical comparisons for SDLM measurements.

			HC (n = 30)		AD (n = 31)		SD (n = 15)		ANCOVA Controlling for age and education			
		Min-Max	*M*	*SD*	*M*	*SD*	*M*	*SD*	*df*	*F*	*p*	Post hoc comparisons
SDLM no-choice condition:												
Accomplishment score		0-16	14.93	1.51	10.68	3.02	10.20	4.84	2, 70	17.77	< .001	HC > (AD = SD)
Time-based score		0-37	22.60	5.04	12.03	4.01	13.80	8.30	2, 70	25.21	< .001	HC > (AD = SD)
SDLM choice condition :												
Accomplishment score		0-16	12.87	1.94	7.10	3.55	8.13	5.10	2, 70	23.95	< .001	HC > (AD = SD)
Total time		0-270”	162.13	53.40	270	0	254.93	39.91	2,70	67.20	< .001	HC < (AD = SD)
Task switching	Task perplexity	*	2.90	1.03	1.57	1.38	2.13	0.99	2, 70	8.44	< .001	HC > AD; HC=SD; SD=AD
Time spent doing nothing	Task perplexity	0-270”	40.47	40.09	112.33	62.04	130.27	68.71	2, 70	18.34	< .001	HC < (AD = SD)
Inappropriate use time	Object perplexity	0-270”	0.93	2.90	8.97	22.92	4.13	11.14	2, 70	1.86	.163	HC = AD = SD
Exploration time	Object perplexity	0-270”	0	0	30.47	49.55	9.33	14.93	2, 70	6.08	.004	AD > HC; HC=SD; AD = SD

Note. HC: healthy controls; AD: Alzheimer’s disease; SD: semantic dementia; SDLM: Sequential Daily Life Multitasking; *M*: mean; *SD*: standard deviation. * No limit.

Concerning the choice and no-choice conditions (illustration in Fig. 4), the two-way ANOVA with the between-participants factor group (HC, AD, SD) and the within-participants factor condition (choice vs. no-choice) revealed a significant interaction effect, $F(2, 73) = 4.46$; $p = 0.015$. Post hoc analyses revealed a substantial difference between conditions in the AD group ($p < .001$; $d = 1.05$), a medium difference in the HC group ($p < .001$; $d = 0.60$), and a scant difference in the SD group ($p = .003$; $d = 0.42$).

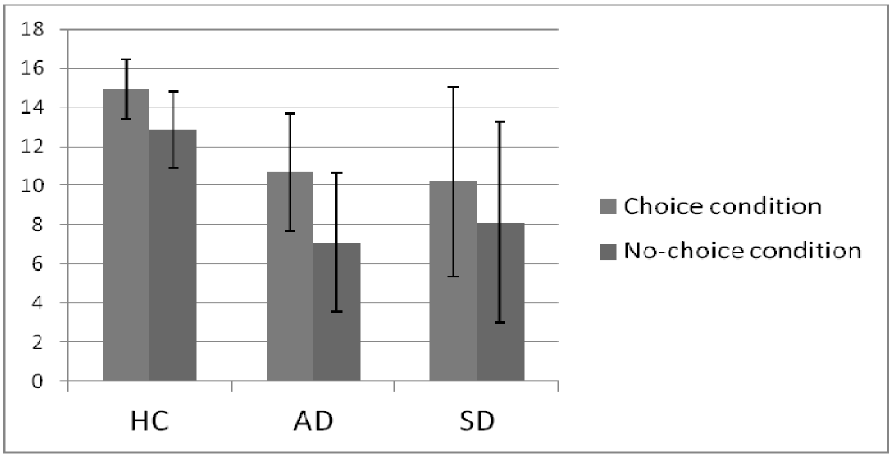


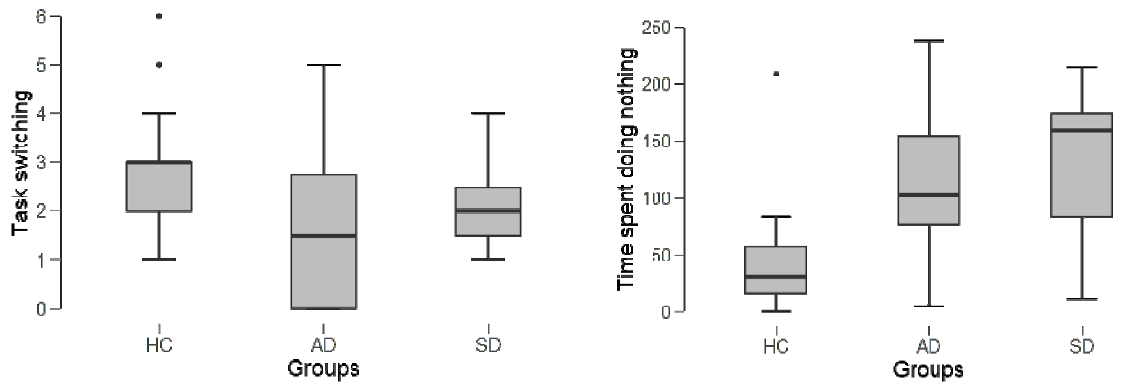
Fig. 4. Performance differences between experimental groups and between experimental conditions on SDLM accomplishment score. Error bars represent the standard error of the mean.

3.3. SDLM Choice condition: detailed analyses

Results are set out in Table 4. Patients with AD or SD exhibited a slightly different pattern of impairment across the measures. First, analyses failed to reveal a significant difference between AD and SD on total time in the choice condition (Tukey = 0.05; $p = .99$) but both groups took considerably longer than HC (HC vs. AD: Tukey = -10.49; $p < .001$; SD vs. HC: Tukey = 8.11; $p < .001$). No significant group effect was found for inappropriate use time. However, patients with AD engaged in significantly less task switching than HC (Tukey = 3.96; $p < .001$), whereas differences were not significant between either SD and HC (Tukey = -2.33; $p = .056$) or SD and AD (Tukey = 0.68; $p = .775$). The AD group also had a longer exploration time than HC (Tukey = -3.49; $p < .004$), whereas differences between patients with SD and HC (Tukey = -.21; $p = .448$) and between patients with SD versus AD (Tukey =

-1.41; $p = .337$) were not significant. Finally, there was no significant difference between the AD and SD groups on time spent doing nothing (Tukey = 1.81; $p = .173$), but both groups spent longer doing nothing than HC did (HC vs. AD: Tukey = -4.49; $p < .001$; HC vs. SD: Tukey = -5.32; $p < .001$) (See Fig. 5 for illustrations).

Task perplexity



Object perplexity

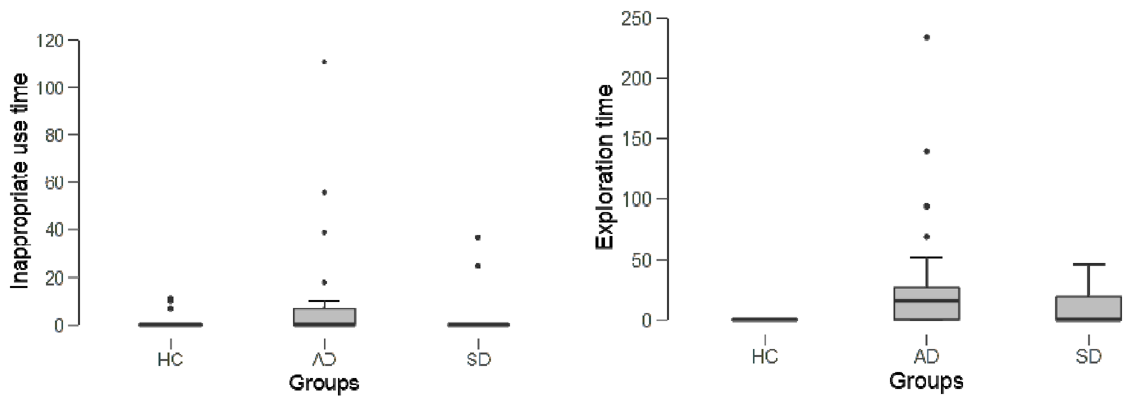


Fig. 5. SDLM choice condition, additional measurements in HC, AD and SD. The boxplots display the interquartile range (minimum, first quartile, median, third quartile, and maximum). Participants with values more than 1.5 box lengths from the upper or lower edge of the box are displayed as outliers.

As shown in Table 4 and Figure 5, there was considerable variability in inappropriate use time, time spent doing nothing, and exploration time. Some patients (with AD or SD) performed in the same way as HC, and did not exhibit these three kinds of behavior at all. We therefore recorded patients who performed above the 95th percentile and conducted chi2 analyses to compare proportions in each group. Results are set out in Table 5. No significant difference was observed between AD and SD.

Table 5
SDLM choice condition, numbers of patients below or above 95th percentile for time measurements.

	AD (n = 31)		SD (n = 15)		Chi-square test		
Percentile	Below 95th	Above 95th	Below 95th	above 95th	*df*	Chi-2	*p*
Time spent doing nothing	9	22	3	12	1	0.428	.513
Inappropriate use time	26	5	13	2	1	0.061	.805
Exploration time	12	19	10	5	1	3.166	.075

Note. AD: Alzheimer's disease; SD: semantic dementia.

3.4 Relations among neuropsychological variables and SDLM measurements

Relations between variables were first examined by considering patients with AD or SD as a single group (n = 46). Results are set out in Table 6. After correction for multiple comparisons (.05/56; $p < .001$ Bonferroni corrected), only a few coefficients met the criteria for statistical significance. The SDLM accomplishment and time-based scores in the no-choice condition were both associated with FACA time. The SDLM time-based score in the no-choice condition and the accomplishment score in the choice condition were both associated with IADL and the episodic score.

Second, we conducted separate analyses for each patient group. For patients with AD, only the SDLM time-based score in the no-choice condition was associated with FACA time (r = -.62, $p < .001$). For patients with SD, only the SDLM accomplishment score in the no-choice condition was associated with IADL (r = -.86, $p < .001$).

Table 6
Correlations between test results (Pearson's r values) in patients with AD or SD.

	IADL	Episodic Score	Executive Score	ToL	ToL Time	FACA	FACA Time
SDLM no-choice condition :							
Accomplishment score	-0.49**	0.45**	0.10	0.39**	-0.05	0.22	**-0.57*** **
Time-based score	**-0.55*** **	**0.49*** **	0.02	0.39**	-0.08	0.29	**-0.48*** **
SDLM choice condition :							
Accomplishment score	**-0.55*** **	**0.59*** **	0.12	0.46**	-0.10	0.34*	-0.42**
Total time	0.25	-0.27	-0.36*	-0.14	-0.01	-0.25	0.12
Task switching	0.44**	0.41**	0.11	0.36*	-0.10	0.27	-0.07
Task perplexity							
Time spent doing nothing	0.32*	-0.30	0.16	-0.10	-0.18	-0.18	0.17
Inappropriate use time	0.17	0.13	-0.10	-0.42**	-0.31*	0.01	0.11
Object perplexity							
Exploration time	-0.05	-0.21	0.22	-0.07	0.06	0.01	-0.12

Note. SDLM: Sequential Daily Life Multitasking. * $p < .05$. ** $p < .01$. *** $p < .001$.

4 Discussion

The objective of the present study was to assess and compare daily life activities and the cognitive processes they elicited in patients with AD or SD. To sum up, both groups exhibited a considerable degree of impairment in their daily life activities, as measured with the SDLM, particularly in the choice condition, and this impairment was associated with semantic and episodic memory failures. The four specific measurements (task switching and time) highlighted specific patient behaviors compared with HC, but they were not associated with any neuropsychological variables, and did not allows us to significantly distinguish between patients with AD versus SD in terms of task versus object perplexity.

4.1 Overall performances of patients with AD or SD on SDLM, BADL and IADL

Our first hypothesis was partially supported by results. Quantitative performances on SDLM (accomplishment score and time-based score) objectified the severity of naturalistic action impairment in both groups of patients, irrespective of experimental condition (choice or no-choice). In addition, informant-based questionnaires (BADL and IADL) showed no significant difference between the AD and SD groups, and overall SDLM performances were associated with caregiver reports (IADL), as demonstrated in previous studies (Giovannetti et al., 2012, 2015). This kind of naturalistic action impairment had already been highlighted in several studies of AD (Giovannetti et al., 2006, 2007, 2008; Okazaki et al., 2009; Opara et al., 2012) but had seldom been reported in SD (Mioshi et al., 2007). This result supports the validity of the SDLM as a clinically meaningful measurement of everyday functioning in AD and SD, but is still subject to debate. It is reasonable to think that the BADL and IADL items seemed more familiar than the SDLM items, given that the SDLM assessment was carried out in hospital (and not at home), and the patients' knowledge of the task may have been different. Moreover, patients' familiarity with objects has long been known to be an important predictor of performance on tool use (Bozeat et al., 2002) and daily life activities such as tea making (Rusted and Sheppard, 2002). An informant-based methodology is also questionable. Recent studies (e.g., Martyr and Clare, 2018) have demonstrated that caregivers underestimate the real functional ability of people with dementia, suggesting the need to use self-rating scales.

4.2 Effect of condition on SDLM and correlations with neuropsychological assessment

Second, we hypothesized that most SDLM performances in the choice condition would be disturbed in both groups of patients, and would be mainly associated with semantic memory impairments in SD and episodic-executive impairments in AD. As predicted, the SDLM appeared to be more difficult in the choice condition than in the no-choice condition for all three groups (HC, AD and SD). This was most noticeable in patients with AD, with a large Group x Condition interaction effect, compared with only a small effect for the SD group. Concerning the neuropsychological assessment, both patient groups exhibited a general and heterogeneous cognitive impairment affecting episodic memory (episodic score), semantic memory (FACA), and executive functions (executive score and ToL). Taking the two patient groups together, SDLM performances (time-based score and accomplishment score) in the no-choice condition were associated with episodic memory and semantic memory disorders (FACA time), whereas the SDLM accomplishment score in the choice condition was only associated with episodic memory disorders. However, in contrast to Buxbaum et al. (1997), our results did not show a strong distinction between the cognitive profiles of patients with AD versus SD. Regarding semantic memory, patients with SD only performed worse than patients with AD on FACA time, and contrary to the object perplexity hypothesis, this deficit was not associated with either SDLM condition in this group. According to the literature, semantic memory deficits have been demonstrated not only in patients with SD, but also in patients with AD, notably with regard to knowledge of manufactured artifacts (Chertkow et al., 2008). Nevertheless, it is also well known that semantic knowledge is not always necessarily involved in the correct use of objects, especially in patients with SD, who show preserved object use despite severe semantic knowledge disorders. The role of semantic memory in gesture production and tool use is still a matter of debate (Bozeat et al., 2002, Negri et al., 2007, Silveri and Ciccarelli, 2009; see also Baumard et al., 2019). Concerning everyday activities, our results tend to suggest that semantic memory is relatively useful in simple, nonambiguous tasks such as the SDLM in the no-choice condition. Furthermore, as previously discussed (Royall et al., 2007; Giovannetti et al., 2012) episodic memory is indispensable for performing everyday activities, especially when multitasking (choice condition). Patients with AD performed more poorly than patients with SD on the SDLM in the choice condition and on episodic memory, but contrary to our task perplexity hypothesis, these impairments were not statistically associated with either SDLM condition in this group. To explore the task perplexity prediction that the difficulties encountered by patients with AD with the SDLM in the choice condition would mainly be associated with specific executive disorders (Royall et al., 2007; Ramsden et al., 2008; Esposito et al., 2010; Giovannetti et al., 2008, 2012; Martyr and Clare 2012), we specifically probed action planning, goal maintenance, and executive control with the ToL and the executive score. Results showed that impaired performances on these tasks were concomitant with those on the SDLM for both patient groups. Overall correlations between ToL and SDLM (choice and no-choice conditions) reached significance in the overall patient population, but did not allow us to statistically confirm a specific link between the two kinds of deficits in patients with AD. In the same way, Roll et al. (2019) concluded that accurately sequencing task steps is associated with multiple aspects of everyday activities, but not with specific kinds of errors or classic executive tasks. Moreover, executive disorders may vary considerably from one individual to another in neurodegenerative diseases, and the role of executive functions in the functional disabilities of patients with AD may therefore appear only moderate at group level (Giovanetti et al., 2012; Martyr and Clare 2012). Patients with SD performed more poorly than patients with AD on the BEC 96 executive score, but this measurement also probed verbal comprehension and lexical abilities, and is probably not a sufficiently pure measurement of executive functions in SD.

4.3 Usefulness of specific SDLM measurements

Third, we predicted that the episodic and executive deficits of patients with AD would entail task perplexity, characterized by longer time spent doing nothing and more task switching, while object perplexity in patients with SD would be reflected in longer inappropriate use and exploration times, associated with semantic memory deficits and sensitivity to distractors. Inspired by the SET (Shallice and Burgess, 1991), the task switching measurement was devised to explore goal maintenance and executive control deficits in patients with AD (Okazaki et al., 2009; Bettcher et al., 2011; Martyr and Clare, 2012).Task switching did not confirm our predictions, as it was significantly lower in the AD group than in the HC group. It was also lower in patients with SD than in patients with AD, even if differences between SD and HC, and between SD and AD, did not reach significance. The simultaneous presence of the material for all three tasks probably led both groups to complete fewer tasks than controls, and they therefore made fewer switches, possibly for different reasons. As it stands, none of the correlations enabled us to identify which cognitive processes were engaged in task switching in any of the groups. Likewise, time spent doing nothing was significantly longer for both patient groups than for HC, and inappropriate use time was relatively rare, concerning just five patients with AD and two patients with SD. Exploration time tended to be longer among patients with AD (Tables 3 and 5), but the nonsignificant difference between the AD and SD groups prevented us from drawing any firm conclusion. These measurements showed that instead of entailing positive symptoms such as object errors or greater switching, perplexity (task or object) seemed to be characterized by an overall reduction in action initiation and action sequences. This was also highlighted by the total time for the choice condition, which was significantly longer for patients with AD or SD, who kept on going until they were stopped by the experimenter, which was not the kind of behavior we observed in HC. As already mentioned in the theoretical introduction, task switching, exploration time, inappropriate use time and, albeit more moderately, time spent doing nothing, could serve as cognitive indicators, integrating or reflecting certain micro-errors, as explored by Balouch and Rusted (2013, 2014). In a longitudinal multiple case study, Balouch and Rusted (2014) demonstrated an increase in errors (omissions) with dementia severity, despite increased error-monitoring through verbal checking. The exploration of verbal and nonverbal cues during time spent doing nothing, exploration time, and inappropriate use time, would perhaps be one way of distinguishing between the behaviors of patients with AD versus SD and their error patterns in everyday action and multitasking.

4.4 Limits and perspectives

The present study had several limitations. Concerning the population, we did not manage to fully match the experimental groups (HC, AD and SD) on age and educational level. Even if SDLM measurements were not associated with age and education level in healthy controls, mismatching may have impacted comparisons of group performances, thus limiting conclusions. Older age is known to impair functional ability (Martyr and Clare, 2012). Furthermore, the SD group was smaller than the AD group. This is a clinical reality, but one which reduces or exaggerates group differences, interaction effects (e.g., the interaction between groups and conditions for SDLM had a large effect in patients with AD, but a modest one in patients with SD), and task correlations. Concerning the method, future research on the SDLM should include more specific semantic memory tasks corresponding to the three different activities (matching and sequential). That being said, it should be noted that experimental items were not identical across the SDLM and FACA. The results of correlation analyses would have been different had the items concerned the same kind of tool in each task, as was proposed in the recent paper by Roll et al. (2019). These authors also demonstrated the usefulness of a picture sequencing test instead of non-domain-specific planning tests such as the ToL. Moreover, we did not question participants' familiarity with the three SDLM tasks. The choice of tasks is always difficult, especially in terms of their ecological validity for assessing everyday functioning. Finally, functional ability should not only be probed using informant-based scales, but also using self-rating scales (Martyr and Clare, 2018). Finally, unlike the SET (Shallice and Burgess, 1991), the choice condition of the SDLM did not really require task interleaving, which is an important parameter of multitasking (Burgess, 2000a, 2000b). This should be corrected in a future version of SDLM, so that task perplexity can be explored further.

5 Summary and Conclusion

Overall, the study confirmed the usefulness of combining a performance-based assessment of everyday action with multi-domain cognitive testing to complement self-/informant-report scales or questionnaires. The impact of SD on everyday functioning, rarely demonstrated, still needs to be confirmed because of the present study's numerous limitations, but our results should encourage researchers to take it into account in the assessment and rehabilitation of patients with SD, as these patients are relatively young. However, understanding the nature of patients' disorders is still a matter of debate and requires further research. Both groups of patients (AD and SD) seemed sensitive to increasing task demands (e.g. multitasking) and moderately disturbed by distractors. More importantly, they displayed a lack of initiative when it came to starting and completing action sequences that was not really associated with executive functioning disabilities. This kind of behavior affected only certain patients with AD or SD (Table 5), once again demonstrating the well-known heterogeneity of their cognitive profiles (Mayeux et al., 1985). Taken together, these observations prompt us to suggest that further research on this topic should consider not only cognitive but also conative, volitional, functions. We know for example that apathy is linked to rule breaking in a modified version of SET (Esposito et al., 2010).

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