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# Category-specific verb-semantic deficits in Alzheimer's disease: Evidence from static and dynamic action naming

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**ABSTRACT**

We investigated the representation and breakdown of verb knowledge employing different syntactic and semantic classes of verbs in a group of individuals with probable Alzheimer's Disease (pAD). In an action naming task with coloured photographs (Fiez & Tranel, 1997. Standardized stimuli and procedures for investigating the retrieval of lexical and conceptual knowledge for action. *Memory and Cognition*, 25(4), 543–569. https://doi.org/10.3758/BF03201129), pAD individuals were impaired for naming actions compared to objects. Verb tense was also affected, with simple-past (e.g., *chopped*) being more difficult to name than the gerundial form (e.g., *chopping*). Employing action-naming with short movies depicting events and states, we contrasted three verb classes based on their hypothetical structural and semantic/conceptual properties: argument structure, thematic structure, and conceptual templates. The three classes were: causatives (*peel*), verbs of perception (*hear*), and verbs of motion (*run*) Overall, results suggest that individuals with pAD are selectively impaired for verb tense and thematic assignment, but not conceptual-template complexity. Methodologically, we also show that dynamic scenes are more ecologically valid than static scenes to probe verb knowledge in AD.

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> … nouns awaken ideas which leave firm traces; … but verbs signify motions, which involve past and future, which are measured from the indivisible present, which even philosophers find very hard to understand. – G. Vico, 1744/1948, p. 137

## 1. Introduction

How are verbs represented in the brain? How are their meanings encoded? How are they used in language comprehension and production? And how are they used to refer to events in the world? For long these questions have been central to psycholinguistics and to cognitive science, more broadly. This is so because verbs play a key role in both language representation and processing, but also because verbs are lexicalizations of special classes of *concepts*, which are the elements of thoughts and higher cognition (Fodor, 1998). Despite their centrality in language and cognition, thus far relatively few studies have investigated verb semantic deficits in Alzheimer's disease (AD; e.g., Grossman et al., 1996b; Grossman et al., 1996a; Grossman & White-Devine, 1998; Kim & Thompson, 2003, 2004; Manouilidou et al., 2009; Price & Grossman, 2005). This is surprising because there is ample evidence of semantic memory deficits in AD affecting diverse categories of concepts (see, e.g., Whatmough & Chertkow, 2002, for review). An investigation of concepts labelled by verbs is thus important because patterns of deficits in AD can be informative regarding both, the nature of semantic categories that verbs encode and, more broadly, the nature of the organization and breakdown of semantic memory. Moreover, since verbs are combinatorial elements – i.e., they require *arguments* to form grammatical sentences – knowledge gained about the pattern of verb deficits can contribute to our understanding of the mapping between syntax and semantic representations of *events* and *states*. Finally, from a clinical perspective, early detection of semantic

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memory and language impairments can be instrumental in AD early diagnosis and remediation (Ahmed et al., 2013; Fraser et al., 2016), with verb knowledge breakdown being one more important piece of this complex puzzle.

A key point in the investigation of verb knowledge is the nature of the linguistic properties that verbs carry, which might be affected selectively in AD, as it occurs in individuals with other aetiologies (see, e.g., Kemmerer & Tranel, 2000a, 2000b; Kim & Thompson, 2004; see also Pillon & d'Honincthun, 2010, for review). For instance, verbs constitute semantic and syntactic classes, which are determined by the number and kind of arguments that verbs take. However, only a small set of studies has employed semantically and syntactically coherent verb classes, that is, verbs with similar kinds and number of arguments, with only a few of these studies showing category-specificity in verb-semantic deficits in AD (see below for a brief review).[1] Additionally, these studies differ considerably with regards to their goals, to the underlying principles accounting for the disruption patterns exhibited by individuals, as well as the type of stimuli used to probe verb knowledge. Despite these differences, several studies seem to suggest that verb deficits in AD may be accounted for in terms of verb semantic complexity.

In the present article, we report a study on the category-specificity of verb semantic deficits in a group of individuals with probable AD (pAD). Our goal was, in particular, to understand the pattern of verb-semantic deficits that may arise in AD based on different types of information supposedly encoded in verbs. In addition, we wanted to advance our knowledge of patterns of semantic dissociations in AD, which can be informative in early diagnostic. And from a theoretical standpoint, we also wanted to rely on verb deficits to provide empirical validity for the types of linguistic information that verbs are taken to encode. Before describing our empirical study, we review linguistic hypotheses on the nature of verb representation as well as cognitive-neuropsychological findings bearing on verb deficits.

### 1.1. Hypotheses on verb representation

The nature of the representation of verb meaning has long been the focus of inquiry in linguistics. At least since the inception of the so-called generative semantics (e.g., McCawley, 1972), the most pervasive view has been that verbs are represented by complex semantic templates, with the complexity metric being a function of the number of internal predicates encoded within the conceptual structure of the verb. These templates are said to specify mainly two types of information. (a) First, they are supposed to encode *syntactic* information, the specification of the number and prominence of arguments that a verb licenses to form grammatical sentences. For instance, a verb such as *to close*, licenses at least one (as in *The door closed*) and maximum two (as in *John closed the door*) syntactic constituents in the grammatical sentences that it partakes. By assumption, the encoding of the number and type of arguments (see below) serves the mapping between linguistic and conceptual structure, that is, between the structural properties of a sentence and its meaning. (b) Second, a semantic template might also specify predicates that determine core properties of the event or state that the verb refers to. In the different versions of lexical semantics (e.g., Jackendoff, 1990; Levin & Rappaport Hovav, 2005), these predicates are taken to be *semantic primitives* (see Engelberg, 2011; and de Almeida & Manouilidou, 2015, for reviews), that is, conceptual elements standing for the nature of the event or sub-event that a verb's carrier sentence refers to. For example, a verb such as *to close* might by hypothesis be represented by a semantic template such as in (1), which encodes semantic primitives such as *ACT, CAUSE* and *BECOME*, with *x* and *y* standing for the syntactic arguments of the surface verb *to close* – namely, the subject *x* and the object *y*.[2]

(1) [[*x* ACT] CAUSE [*y* BECOME <*closed* > ]]

Another characteristic of a template such as (1) is that it allows for the encoding of both transitive (*John closed the door*) and intransitive (*The door closed*) alternations, in which case the intransitive variant is represented by an internal constituent (viz., [*y* BECOME <*closed* > ]) of the transitive template. Table 1 exemplifies different levels of representation for verb knowledge together with the predictions of the present study, discussed below.

In addition to information about arguments that map onto syntactic constituents, and predicates that determine core properties of verb meaning, it has

also been proposed that verbs encode what has been called semantic or *thematic* roles (Chomsky, 1981; Parsons, 1990). These are semantic properties assigned to the arguments of the verb specifying the roles played by its syntactic arguments (e.g., subject, object) in the event or state that the verb refers to. For instance, in a sentence such as *John closed the door*, *John* is taken to be the *Agent*, and *door* the *Patient* or *Theme*. These roles help establish the mapping between syntactic structure and semantic representation. This mapping is often said to rely on what has been termed "thematic hierarchy" (Fillmore, 1968; Grimshaw, 1990), which stands for a canonical order of the roles typically attributed to the syntactic arguments of a verb in a sentence. It has been argued that a canonical order is important to establish a default role for syntactic positions, with particular roles having more prominence than others. Thus, for instance, there is general agreement that the *Agent* role is more prominent than others, typically being assigned to the sentence constituent in the subject position. The least prominent role is usually the *Theme* and is assigned to the internal complement of the verb (see Manouilidou & de Almeida, 2009).

While the linguistic status of thematic roles and their very ontology are far from consensus in linguistics (e.g., Levin & Rappaport Hovav, 2005; Newmeyer, 2002), an empirical – viz., experimental – investigation of these elements and the nature of templates more broadly is crucial for understanding how verb meaning is represented and how it may breakdown in brain injuries and diseases.

### 1.2. Verb deficits in Alzheimer's disease

Several studies investigating verb deficits in individuals with AD have focused on the complexity associated with semantic templates such as (1), as well as thematic properties of verbs. For instance, Kim and Thompson (2004) examined the effects of verb semantic complexity in 14 individuals with pAD and 10 individuals with agrammatism. They employed action naming, sentence completion (with pictures showing events), grammaticality judgment, and narratives based on a picture book. Overall, results showed that individuals with pAD had more difficulty naming and producing two-argument verbs (*x catch y*) compared to one-argument verbs

**Table 1.** Hypothetical levels and types of representation of verb information, their functions, and predictions for the Dynamic Action Naming Task.

| Level of Verb Representation | Types of Representations | Examples | Sample Functions | Performance Predictions for the Dynamic Action Naming task * |
|---|---|---|---|---|
| Conceptual | meaning postulates, entailments | *x PEEL y → y PEEL*<br>*x HEAR y → x PERCEIVE SOUND (y)*<br>*x RUN → x MOVE* | licensed inferences, conceptual relations, categorization | |
| | conceptual templates | [*x ACT* [*CAUSE* [*y BECOME* < *PEELED* > ]]]<br>[*x PERCEIVE* < *HEAR* > *y*]<br>[*x MOVE* < *RUN* > ] | representation of events and states incorporating ontological primitive predicates and syntactic positions | *peel* > *hear* > *run* |
| | atomic concepts | *PEEL, HEAR, ACT, GO, RUN, CAUSE* | meaning of individual concepts, ontologically primitives | |
| Thematic | thematic structure | *[peel [Agent, Theme]]*<br>*[hear [Experiencer, Theme]]*<br>*[run[Agent]]* | predicate structure with canonical roles assigned by order of prominence | *hear* > *peel* > *run* |
| | thematic hierarchy | *Agent* > *Experiencer* > *Instrument* … > *Theme* | canonical order for mapping roles to arguments | |
| | thematic roles | *Agent, Experiencer, Instrument, Theme* | roles attributed to participants in events/states | |
| Syntactic | argument structure | *peel (x, y), hear (x, y), run (x)* | constituents necessary to form grammatical sentences; elements that "saturate" the structure | *hear* = *peel* > *run* |
| Morphological | stems | *peeled, hearing, running* | complex lexical tokens | |
| | free morphemes (roots) | *peel, hear, run* | simplex lexical tokens | |
| | bound morphemes | *en-, -en, -ify, -ed, -ing* | English morphemes that attach to verbs or that form verbs by attaching to other grammatical categories; representation of temporal and aspectual properties of events/states | |

* > Denotes greater impairment.

(*x snore*). However, this argument structure effect was not consistent as individuals with pAD had less difficulty with three-argument verbs (*x give y to z*) than with two-argument verbs, in contrast with individuals with agrammatic aphasic, who showed a linear argument-structure complexity effect. Together, Kim and Thompson take these results to be an effect of a "bottom-up" verb semantic complexity breakdown, suggesting that verbs are represented in a decompositional form, akin to semantic templates. More specifically, in order to account for the inconsistent disruption pattern displayed by individuals with pAD, they suggest that verb taxonomies are represented in a three-level hierarchy, much like that of noun taxonomies: the top level being analogous to superordinate categories, the middle level being analogous to basic categories, and the lower level being analogous to subordinate categories. Verbs at the bottom of the hierarchy, namely specific verbs (e.g., *scrub*), are said to be semantically complex as they are hypothesized to pack more internal predicates, many of which are shared with neighbouring verbs in the hierarchy, such as heavy/general verbs (e.g., *clean*) found at the intermediate level, and light verbs (e.g., *do*) found at the top of the hierarchy. As a result, should a given verb be impaired, individuals will retrieve neighbouring verbs with intact semantic representations. According to Kim and Thompson, this would explain why individuals with pAD showed a retrieval advantage for general verbs as opposed to light verbs in the sentence completion task. However, this explanation seems to be at odds with the nature of templates, as primitives of light verbs are also taken to be constituents of specific and heavy verbs: for instance, *GO* might be a constituent of *run,* on the assumption that *run* is represented by a complex template such as (2), following Pinker's (1989) analyses (also adopted by Breedin et al., 1998; and Kim & Thompson, 2004).

(2) $[_{\text{Event}}$ [ACT $[_{\text{Thing}}$ *X* $[_{\text{Manner}}$ *running*$][_{\text{Event}}$ GO $[_{\text{Thing}}$ ([*X* ]), $[_{\text{Path}}$ [FROM ($[_{\text{Place}}$ ]) TO ($[_{\text{Place}}$ ])]]]]

Thus, if verb meaning is represented by a complex template, losing a light verb such as *go* (or, more properly, its conceptual representation *GO*), should lead to the loss of the heavy one, on the assumption that *GO* is a constituent of a heavy verb such as *run*. In other words, having *GO* should be a *necessary* condition for having *run* and losing the former should affect the meaning of the latter. Arguably, if one removes *GO* from the template in (2), one loses what might be its most important predicate, the one that denotes motion of the agent through a path. Additionally, should a given verb be impaired, it is not entirely clear whether information about higher or lower predicates should be accessible: if verbs are composites of complex predicates, the lower the verb is in the hierarchy, the worse the performance should be, on the assumption that these hierarchies are psychologically real.[3] Given these theoretical problems, the results of this study seem to suggest that it is a verb's *argument structure* what might be affected in individuals with pAD, rather than semantic complexity per se, even if the argument-structure effects were not consistent across verb types.

The reason for favouring an argument structure effect explanation rather than a semantic-template complexity effect for Kim and Thompson's (2004) study is that numerous other studies have also found that the pattern of deficits in AD can be better accounted for by the number of arguments and the types of thematic roles that these arguments are assigned by different verb classes. These effects prevail even when other semantic variables appear to affect verb knowledge. For instance, Grossman et al. (1996a) set out to investigate the structural and semantic properties associated with three classes of verbs, which they classified as *cognition* (e.g., *think*), *perception* (e.g., *hear*), and *motion* (e.g., *crawl*) in a group of 25 individuals with pAD. In the first task, a triadic comparison, participants were presented with three verbs at a time and asked to select the two that they felt "go best together" (p. 374). In the second, a sentence judgment task, participants were presented aurally with sentences containing the verbs from the same classes and instructed to rate the goodness of each sentence on a 1-to-5 scale. These verb classes, by hypothesis, allow for different argument structures. For instance, a psychological (or cognition) verb allows for a sentential complement (SC; *Jim remembered* [*that the story was true*]) while a motion verb allows for a prepositional phrase (PP; *Mary jumped* [*over the wall*]). However, crossing these frames can result in ungrammatical, or at a minimum less acceptable sentences (?*Fred remembered* [*on the shore*];?*Larry jumped* [*that the*

*horse was over the fence*]). In the triadic comparison task, pAD's verb clusters differed slightly from controls mostly by mixing verbs such as *remain* with the psychological/cognition verbs (e.g., *remember*, *think*). But the main finding of this study was that individuals with pAD had greater difficulty judging the goodness of sentence frames. Thus, for instance, pAD individuals gave higher ratings than healthy controls to sentences with motion verbs that had SC and to sentences with cognition verbs that had PP complements. Also, the pAD group's ratings were lower than controls for sentences in which verbs were in their most canonical frames. These results seem to suggest that the difficulty that pAD individuals have with verbs is primarily in argument structure – that is, matching the proper internal arguments or adjuncts to verbs. Thus, despite their performance in the triadic task deviating from controls only "modestly" (p. 383), the sentence-rating task consistently shows the individuals with pAD's difficulty judging the grammaticality of sentence frames.

Along similar lines, Grossman and White-Devine (1998) investigated the role of argument structure and thematic roles of both simple transitive (e.g., *kiss*) and causative (e.g., *awaken*) verbs, in individuals with pAD. Participants performed a sentence comprehension task on both passive and active sentences that contained the two verb types (e.g., *The boy kissed the girl* and *The mother awakened the baby*), with questions that either probed about the *Agent* (e.g., *boy*, *mother*), *Patient* (*girl*, *baby*), or *Theme* (objects that underwent an action) of the sentence. That is, participants were required to answer questions such as *Did the mother awaken?* or *Did the baby awaken*? A key difference between simple transitive and causative verbs, according to Grossman and White-Devine, is that while the boy is the *doer* of the action in *The boy kissed the girl*, the baby is the agent of its own awakening in *The mother awakened the baby*. Recall that, by assumption, causatives are represented by semantic templates like (1) in which the object that undergoes a change of state (*the door* in (1) or *the baby,* in the Grossman & White-Devine study), is the "subject" of its own predicate (as in [*y* BECOME <*awake* > ]). Thus, the mother *causes* the baby to become awake. In addition, the assumption is that the thematic roles associated with these verbs map *atypically* to agents in the subject position, which the authors argue imposes a higher demand on cognitive resources. Results showed that individuals with pAD produced significantly more mistakes in sentences with lexical causative verbs – for instance, answering "yes" more frequently to *Did the mother awaken*? However, the atypicality described by Grossman and White-Devine can be disputed. In both sentence types above, the subjects (*boy*, *mother*) are indeed assigned the *Agent* role. Rather, the difficulty that causatives may engender is that they alternate between transitive and intransitive frames. In this case, it is possible that individuals with pAD make more mistakes with these sentences because they have less attention or memory resources to compute inferences of the sort *The mother awakened the baby → The baby awakened*, which is what the task requires. Instead participants may be led to perform the wrong inference, but one that is compatible with the core meaning of the verb frame (*The mother awakened the baby → The mother awoke*). Notice that *The mother awoke* is compatible with the intransitive reading of the verb *to awake*. This might not signal a verb deficit per se, but rather a deficit computing the *entailments* of the sentences given the two possibilities that the lexical causative type affords. Another possibility is that the *morphological* causative *to awaken* engenders a level of complexity beyond the simpler argument or thematic structure of *lexical* causatives: this is so because *The mother* is assigned the *Agent* role not by the verb root but by the causative morpheme *–en*, with *the baby* being the agent of *awake*.[4] It should be noted that Grossman and White-Devine's study does not require the subject to simply name an action or fill-in a frame, but it rather encourages inferential processes that might lie beyond verb knowledge. In summary, in this study, the locus of the deficit might be in the computation of alternative structures that the verb allows for, not on thematic or conceptual-structure properties of the constructions.

A more recent study (Manouilidou et al., 2009), however, seems to show that the source of verb deficits in AD is the argument structure level of representation, with marked difficulty in the assignment of thematic roles to arguments, in particular when sentences deviate from canonical Subject/*Agent*-Verb-Object/*Theme* frames. In their study, Manouilidou et al. presented 10 individuals with pAD and matched controls with sentence frames containing a gap such as in *The boy _____the thunder*. Participants

were required to select a verb that best fit the frame, among four alternatives. For example, the alternatives were *fear*, *frighten*, *cook*, *sleep*. The first, *fear*, is a Subject-Experiencer verb because it assigns the role of *Experiencer* to the noun phrase in the subject position; the second, *frighten*, is taken to be the reverse, a psychological verb that is deemed Object-Experiencer because it assigns the role of *Experiencer* to the noun phrase in the object syntactic position. The two other verbs were distractors representing alternatives that would deem the sentence ungrammatical (*sleep*) or anomalous (*cook*). In contrast to these *Experiencer* verbs, Manouilidou et al. employed canonical *Agent-Theme* sentences (e.g., *The gang [stole] the car*). Crucial to their comparisons were the contrasts between the two sub-classes of *Experiencer* verbs and between these and the *Agent-Theme* frames. Manouilidou et al. report two main findings. The first was that pAD individuals had greater difficulty with the two kinds of *Experiencer* sentences compared to *Agent-Theme* sentences, suggesting a deficit with structures that deviate from the canonical agentive argument structure. The second was that the more the sentences deviate from canonical structures, the more difficult they are for individuals with pAD. Evidence for this was obtained in the contrast between Subject-Experiencer (*fear*) and Object-Experiencer (*frighten*) sentences: when the *Experiencer* role, typically assigned to the subject position, is assigned to the object position, it yields a structure such as [*Theme*, *Experiencer*]. Notice that this structure is less canonical not only because it lacks the most prominent *Agent* role but also because it assigns the second-most prominent role (*Experiencer*) to the object position instead of the subject position. Taken together, these results seem to point to thematic structure – rather than other properties of verbs – as the main source of difficulty for individuals with pAD.

### *1.3. Verb classifications*

As can be seen in the review above, key to understanding the pattern of verb deficits is a proper characterization of the nature of verb representations. Moreover, a proper classification of verb types seems to be crucial for investigating how the semantic system may be affected in AD. For instance, it may be the case that verbs are clustered according to the components represented in their hypothetical semantic templates. If so, one might expect that semantic deficits pattern along these components. In fact, this view is compatible with a decompositional, feature-based view of deficits whereby concepts sharing similar features tend to be affected together giving rise to effects of category-specific semantic deficits. (see de Almeida, 1999a, for discussion). Another way of classifying verbs might be according to their argument structure together with the kinds of thematic roles they assign to their arguments. This view assumes that the nature of verb-semantic deficits might affect the number and types of thematic roles that verbs assign. While these two views are not incompatible, the first view is committed to predicate decomposition (the likes of *GO*, and *CAUSE*, as in (2)), while the second is simply committed to the structure and role of arguments without appealing to covert predicates. Lastly, it is possible that only argument structure – devoid of content – forms the basis of verb groupings, which would be evidenced by agrammatical performance by subjects. This hypothesis could be rejected, in principle, based on the studies discussed above – such as Grossman et al. (1996a), Price and Grossman (2005) and Manouilidou et al. (2009) – showing that individuals with pAD are indeed sensitive to grammatical violations, usually rejecting syntactically anomalous constructions.

Close inspection of the verbs and verb classes used in the studies we reviewed above shows that their classifications cut across each other in terms of semantic and syntactic variables. For instance, Kim and Thompson (2004) classified their verbs mainly in terms of number of arguments, not in terms of hypothetical semantic templates constituents (thus, including verbs such as *crawl* and *pray* in the same category). Along the same lines, Grossman et al. (1996a) classified a verb such as *listen* as a *motion* and *perception-cognition* verb; however, it is not entirely clear how *listen* involves motion (other than that of air waves). Additionally, Grossman et al. (1996a) relied on a very small set of verbs, namely 3 motion, 3 cognition, and 4 perception verbs, limiting significantly the scope of their results. In other cases (e.g., Price & Grossman, 2005) there may be a conflation between what *thematic* information is and what is world knowledge or pragmatic information bearing on verb knowledge. It is clear, thus, that given the methodological issues

associated with previous studies investigating verb deficits, better-refined verb classifications are needed before drawing conclusions about the nature of these deficits in AD.

### 1.4. The present study: Strategy and predictions

#### 1.4.1. A living/nonliving dissociation?

In order to investigate verb-semantic deficits in individuals with pAD, we relied on the following strategy. We first wanted to determine whether our sample of pAD individuals showed the classical living/nonliving dissociation found in the literature, that is, whether our pAD group would have more difficulty naming living things compared to nonliving things (e.g., Zannino et al., 2007; but see Laws, Adlington, et al., 2007, for a review of variables). This was important for two main reasons. First, dissociations of categories such as living/nonliving have become a hallmark of semantic impairment in AD and, thus, it was expected that if our pAD participants were to show a category-specific semantic deficit along those lines, it would effectively characterize their impairment in semantic memory. Second, since our goal was to understand the patterns of semantic deficits for concepts labelled by verbs, it would be important to have a parameter for semantic impairment – namely, living/nonliving concepts labelled by nouns – against which we could determine the severity of verb impairment, should it be found. And third, verbs name events and states, and usually these – at least events – are dynamic, unfolding over time: they often involve *agents* which are characterized as being living things, and objects (or nonliving things) that may undergo a change of state. Even in the case of mental states – as in psychological and perceptual verbs – referents are more complex than simple static objects (Gleitman, 1990). Thus, we reasoned that pAD individuals with a living/nonliving dissociation would be more prone to show dissociations of verb *classes*, which also vary regarding the degree to which they represent "living" situations. To this end, our first task was a living/nonliving dissociation employing a picture-naming task for objects representing diverse semantic categories.

#### 1.4.2. An action/object naming dissociation?

In addition to characterizing a living/nonliving dissociation, then, we were interested in determining whether or not pAD individuals would have more difficulty with naming events and states as opposed to naming objects. This dissociation has been documented in the literature (e.g., Almor et al., 2009; see also Pillon & d'Honincthun, 2010, for review), with many studies suggesting that individuals with pAD have marked difficulty naming actions and states as opposed to different categories of objects. As such, we predicted that a general impairment with verbs as well as difficulties with verb specific features within our sample would be good predictors of verb semantic *class* dissociations. We were also interested in determining the degree at which a possible verb deficit would be reflected in the use of verb tense features. Thus, the second task involved naming colour pictures depicting events and states using two verb tenses, the gerundial form and the simple past (Fiez & Tranel, 1997). We reasoned that the appropriate use of verb knowledge might also require retrieving the proper morpho-syntactic features that correspond to a depicted scene and its temporal properties, on the assumption that morphemes such as *-ing* or *-ed*, for example, are overt realizations of these properties. We also examined a verb vs. noun dissociation by contrasting performance in this action naming task with data from the first, living/nonliving object naming task.

#### 1.4.3. Level of verb-knowledge impairment

Most importantly, we were interested in determining the extent to which a possible verb deficit might affect semantic classes of verbs – thus yielding a possible category-specific deficit. For this particular goal, we produced a set of stimuli that could be contrasted at three hypothetically different levels of representation, as discussed above: argument structure (the valence or number of obligatory syntactic constituents), thematic roles (the roles assigned to arguments and their possible hierarchy), and semantic template complexity (the number and nature of semantic predicates that might constitute verb class template meaning). We reasoned that this manipulation would allow us to detect the level of semantic impairment for verbs – if any – thus informing how verbs might be clustered into classes and, additionally, support or refute empirically proposals for the nature of verb representation.

For the third task, then, we employed a dynamic action-naming task, with video clips depicting three

verb classes: lexical causatives (verbs that denote a change of state in the object caused by an agent; e.g., *peel, squeeze*), movement verbs (verbs that denote body movements; e.g., *run, jump*), and perception/psychological verbs (verbs that are tied to the perception of an entity or to psychological states; e.g., *hear, watch*).[5] Our predictions for this task were linked to different hypotheses concerning the nature of verb knowledge representation, and in particular to the nature of the information (structural, semantic) that binds verbs into classes. A summary of our predictions appears in Table 1. We predicted the following: verbs deemed more complex structurally (argument structure) or semantically (thematic structure or semantic template) would be the hardest to elicit. This complexity hypothesis is consistent with several studies on verb meaning stemming from the psycholinguistics literature (see de Almeida & Manouilidou, 2015, for a review), yielding one of the following patterns:

- **Argument structure: *perception* = *causative* > *movement verbs***: Regarding argument structure, this prediction relies on number of arguments, with verbs requiring more arguments to form grammatical sentences being the most difficult – akin to the argument-structure complexity hypothesis (e.g., Thompson, 2003). If so, we would expect a pattern of performance such that verbs with two arguments (causatives and perception[6]) would be more difficult than verbs with one argument only.
- **Thematic structure with thematic hierarchy: *perception* > *causative* > *movement verbs***: If it is thematic structure, together with thematic hierarchy, what determines the level of impairment in verb knowledge, we would find thematic-role effects. A key difference between this prediction and the one made for argument-structure effects is that verbs that assign an *Agent* role should be easier to name than verbs that do not. By assumption, a subclass of perception verbs assigns an *Experiencer* role to the subject position, which is non-canonical, following several thematic hierarchy proposals (see Manouilidou & de Almeida, 2009, for review), and thus should be more difficult to name.
- **Conceptual template: *causative* > *perception* > *movement verbs***: If verb classes are represented according to conceptual templates, a loss of template constituents would signal a loss of verb meaning: by assumption, losing *CAUSE* would imply losing all verbs whose templates carry the hypothetically primitive concept *CAUSE* among their constituents – and so on for *GO* and other key predicates that are taken to be *necessary* constituents of verb meanings. Since causatives have greater template complexity – conceived as two arguments and more internal predicates (viz., *ACT*, *CAUSE*, *BECOME*) – they were hypothesized to be more prone to impairments than the simpler movement verbs (in their intransitive variants – like *run*), which might contain one predicate (e.g., *GO* or *MOVE*). Crucially, this pattern of impairment would suggest that (a) verbs might be clustered according to the predicates they share and (b) verb impairment in AD affects classes that contain more predicates in their hypothetical templates than those whose templates are simpler. An additional theoretical implication of this pattern of results is that (c) verbs might be represented by complex predicate structures as hypothesized by several semantic theories (e.g., Jackendoff, 1990; Levin & Rappaport Hovav, 2005).

#### *1.4.4. Static vs. dynamic scenes*

While most studies investigating verb knowledge impairments in individuals with pAD have employed static line drawings to depict objects and events (e.g., Fiez & Tranel, 1997; Kim & Thompson, 2004; White-Devine et al., 1996), we aimed to increase ecological validity. We reasoned that motion pictures might better capture the nature of what verbs denote: causatives imply action by an agent and a change of state in an object; perceptual and psychological states often imply changes in facial expression; and clearly motion verbs imply a body (the agent) moving in space. Thus, we predicted that individuals with pAD would be better overall in naming dynamic scenes than they would be in naming static pictures depicting events and states, for they would be presented with information that, by hypothesis, better represents the temporal and spatial dynamics of events, thus potentially modulating the effects of verb knowledge impairment.

In summary, the present study aimed to make two main contributions to the investigation of verb deficits in AD. The first bears on the linguistic properties that are said to bind different classes of verbs

together. As previously mentioned, thus far few of the studies investigating verb dissociations in AD have based their classifications on properties that are hypothesized to be common to verb classes (e.g., Levin & Rappaport Hovav, 2005), such as the predicates that constitute verb templates. Second, our study also aimed to further contribute methodologically to our understanding of verb representation and to the investigation of verb deficits in AD. Although a few other studies have investigated verb deficits using dynamic scenes in other brain damage populations (Tranel et al., 2008) and other forms of dementia (d'Honincthun & Pillon, 2008), to our knowledge, the present study is the first to employ dynamic scenes with pAD individuals.

## 2. Method

### 2.1. Participants

Ten pAD individuals (7 females) and 11 healthy elderly controls (7 females) were recruited for this study. In addition, another group of 15 healthy elderly individuals participated in a norming task. All participants were native speakers of English (i.e., learned English before the age of 5 and have used it as a dominant language) and had normal or corrected-to-normal vision. In the case of control participants, they reported having no history of any major psychiatric or neurological disease. These groups are described in more detail below. All participants gave written informed consent. In the case of pAD participants, consent was signed either by the individual or by a caregiver with the consent of the individual. The study was approved by the ethics board of the Douglas Mental Health University Institute (pAD individuals) and the Concordia University human research ethics committee (control and norming participants).

#### 2.1.1. Individuals with probable Alzheimer's disease

The 10 pAD individuals were recruited from the Memory Clinic of the Douglas Mental Health University Institute, in Verdun, Quebec. The diagnosis was in adherence to the criteria established by the National Institute of Neurological and Communicative Disorders and Stroke, Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA; Mckhann et al., 1984). The pAD individuals' medical history, brain imaging (e.g., CT scans), laboratory tests (e.g., blood tests) and neuropsychological assessments indicated that their dementia symptoms could not be better accounted for by an illness other than Alzheimer's.[7] Clinical evaluations and results of the Mini-Mental State Examination (MMSE; Folstein et al., 1975) and Boston Naming Test (BNT; Kaplan et al., 1983) indicated that all pAD individuals showed mild to moderate dementia. All participants were capable of complying with the requirements of cognitive testing. Individuals with pAD's and controls' demographic and neuropsychological data are presented in Table 2.

#### 2.1.2. Healthy controls

The 11 healthy controls were recruited from senior residences in Montreal, Quebec, and Kingston, Ontario. All participants scored 26 and above on the MMSE (see Table 2). They were matched to individuals with pAD in terms of age and education. There were statistically significant differences between pAD individuals and healthy controls in terms of both their MMSE, $F(1, 19) = 49.03$, $p < .0001$, and BNT scores, $F(1, 19) = 67.74$, $p < .0001$.

#### 2.1.3. Elderly norming group

Fifteen healthy seniors provided norming data on naming agreement for the dynamic action-naming task. They ranged in age from 58 to 82 years ($M = 71.6$, $SD = 7.8$), and their years of education ranged from 11 to 15 years ($M = 12.67$, $SD = 1.44$). Their mean MMSE and BNT scores were 28 and 56, respectively. Five of the normal elderly individuals were tested at the Psycholinguistics and Cognition lab at Concordia University, and the other 10 were tested in their homes, in Kingston, Ontario.

### 2.2. Design and materials

We conducted three main tasks: (1) a living/nonliving task with line drawings (Snodgrass & Vanderwart, 1980) to assess pAD individuals' knowledge of semantic categories employing noun labels; (2) an action naming task with static pictures of events and states (Fiez & Tranel, 1997), to assess pAD individuals' verb knowledge as well as to test for a possible noun/verb dissociation; and, finally, (3) a dynamic action naming task, with movies of events and states to test pAD individuals for the possibility of a verb-class dissociation along the lines of linguistic

**Table 2.** Demographics and cognitive test scores of individuals with pAD and healthy controls.

| Individual | Gender | Age | Years of Education | BNT | MMSE |
|---|---|---|---|---|---|
| Individuals with pAD | | | | | |
| P001 | F | 76 | 12 | 28 | 23 |
| P002 | M | 76 | 9 | 21 | 22 |
| P003 | M | 76 | 15 | 41 | 22 |
| P004 | F | 82 | 11 | 41 | 24 |
| P005 | F | 92 | 6 | 17 | 19 |
| P006 | F | 68 | 11 | 37 | 19 |
| P007 | F | 89 | 11 | 17 | 25 |
| P008 | M | 74 | 11 | 38 | 24 |
| P009 | F | 67 | 11 | 33 | 20 |
| P010 | F | 70 | 10 | 29 | 26 |
| Mean | | 77 | 10.7 | 30.2 | 22.4 |
| (SD) | | (8.4) | (2.6) | (9.4) | (2.5) |
| Healthy Controls | | | | | |
| H001 | F | 60 | 11 | 53 | 28 |
| H002 | F | 69 | 11 | 56 | 28 |
| H003 | F | 71 | 10 | 53 | 30 |
| H004 | M | 83 | 16 | 52 | 26 |
| H005 | F | 81 | 11 | 55 | 30 |
| H006 | F | 81 | 14 | 53 | 28 |
| H007 | F | 82 | 11 | 49 | 26 |
| H008 | F | 63 | 15 | 56 | 30 |
| H009 | M | 86 | 11 | 59 | 30 |
| H010 | M | 64 | 11 | 59 | 29 |
| H011 | M | 66 | 17 | 60 | 30 |
| Mean | | 73 | 12.6 | 55.0 | 28.6 |
| (SD) | | (9.5) | (2.5) | (3.4) | (1.6) |

proposals for verb representations, as discussed above. These tasks are described in more detail below.

### 2.2.1. Stimuli

#### 2.2.1.1. Naming living and nonliving things task.

Picture stimuli consisted of 118 black and white line drawings from Snodgrass and Vanderwart's (1980) corpus, with 53 representing living things, and 55 nonliving things. In addition, 10 items, half from each category, were used as practice trials. Living things included animals, insects, fruits, vegetables and body parts, whereas nonliving things included tools, vehicles, household items, clothing items and musical instruments. On the basis of the norming values provided in the Snodgrass and Vanderwart's corpus, the stimuli within the semantic categories of living and nonliving things were matched according to naming agreement ($F$ (1, 107) = .77, $p$ = .38), visual complexity ($F$ (1, 107) = .75, $p$ = .39), and lexical frequency ($F$ (1, 104) = .009, $p$ = .92). See Appendix 1, in Supplementary Materials.

#### 2.2.1.2. Naming static events and states.

Stimuli consisted of 103 single and paired coloured photographs depicting static scenes from Fiez and Tranel's (1997) Action Naming Test. The experimental session consisted of 95 photographs (75 single and 20 paired). The 75 single photographs depicted agents engaged in ongoing actions, thus eliciting verbs in the gerundial form (e.g., *cutting*). The 20 pairs of photographs depicted change-of-state events, with one picture depicting a person/object before a given action (e.g., a banana), and another, the same person/object after the action (e.g., a peeled banana), which were supposed to elicit regularly inflected verbs in the pat-tense form (e.g., *peeled*). The experimental session was preceded by a practice session consisting of eight photographs, half single, half paired. Ten pictures from the original Fiez and Tranel set were removed because they were the basis for the dynamic action naming video clips, described below. Single and paired photographs were matched according to image agreement, name agreement, visual complexity, familiarity, and lexical frequency, according to Fiez and Tranel's (1997) published norms (see Appendix 2, in Supplementary Materials).

#### 2.2.1.3. Action naming with movies of events/states.

Twenty-nine realistic movies depicting events and states were shot by NiteVision productions (Montreal, Quebec). In order to maintain visual similarity, we employed only three actors and the same black background throughout all movies. To reduce visual complexity, an attempt was made to restrict the focus of the movie to only the parts of the scenes that were necessary to portray the action (e.g., *watching* included only a woman looking at a TV with no other objects).

The movies were designed to probe three different verb categories, each classified in accordance to specific linguistic characteristics: lexical causative verbs, movement verbs, and perception verbs (see Figure 1 for sample frames, and Supplementary Materials for sample video clips in each verb class). Verbs were selected from Levin (1994). The categories were arranged such that three levels of verb representation could be tested according to semantic and syntactic complexity. In the present case, complexity was operationalized as involving three types of information: argument structure, thematic structure, and semantic templates. As discussed above, for argument structure, complexity involved the number of arguments required by the verb to form grammatical sentences. Thematic-

**Figure 1.** Video frames depicting three verb classes studied in the Dynamic Action Naming Task. From top row: *Peeling,* representing the category of lexical causatives, *running*, representing the category of (body) movement verbs, and *listening*, representing the category of perception/psychological verbs. See text for details about the properties of these categories.

structure complexity was conceived as greater deviation of thematic hierarchy, viz., with verbs assigning less canonical *Experiencer-Theme* roles as being more complex than those with *Agent-Theme*, following the thematic-hierarchy violations found in previous studies (Manouilidou et al., 2009; Manouilidou & de Almeida, 2009; Piñango, 2006) And, finally, semantic-template complexity was conceived as the number of predicates postulated to be represented within the verb's class template.

*Lexical Causative verbs*. The lexical causative verbs included *peeling, bending, twisting, crumpling, flipping, squeezing, crushing, spilling, folding,* and *bouncing*. These movies all depict one agent interacting with a given object (e.g., a woman's hand squeezing an orange). Five of Fiez and Tranel's (1997) coloured pictures were used as models for shooting the videos, with similar camera angle, object position, and type of object.

*Movement verbs*. The movement verbs consisted of *tiptoeing*, *skating, walking, running, climbing, hopping, leaping, swinging, rolling,* and *crawling*. The movie scenes either depicted one agent moving in space (e.g., *tiptoeing*) or interacting with an object (e.g., *climbing* a ladder, *swinging* in a swing).

*Perception verbs*. The perception verbs included were *scanning, looking, smelling, peeking, glaring, staring*, *listening, tasting,* and *watching*. All movie scenes involved one agent, except for the depiction of *staring*, which required two people, one starring and one being starred at. In general, the agent either interacted with an object (e.g., *smelling* a flower, *watching* TV, visually *scanning* a paper, *tasting* yogurt), or perceived a stimulus (e.g., *looking, peeking, glaring, listening, staring*), often depicted with the use of hand gestures (e.g., *listening, looking, peeking*), or facial expressions (e.g., *glaring, staring*). Fiez and Tranel's (1997) coloured pictures depicting *looking*, *smelling*, *peeking*, *glaring*, *listening*, and *watching* were also used as models.

The full set of movies we employed can be obtained from http://psycholinguistics.weebly.com/materials.html.

### 2.3. Procedures and apparatus

Testing was completed in two one-hour sessions, with sessions being one week apart, or, if in one session, in a counterbalanced order. Two pAD individuals were tested at the Memory Clinic of the Douglas Mental Health University Institute, while the other eight were tested in their homes. Six of the control participants were tested in their homes, and the remaining five were tested at the Memory Clinic of the Hotel Dieu Hospital in Kingston, Ontario. Participants were tested individually in a quiet room seated in front of a Mac laptop running Psyscope (Cohen et al., 1993). Participants received instructions aurally by the experimenter. The instructions were repeated after the practice trials.

#### 2.3.1. Naming living and nonliving things

Line drawings were presented to participants one at a time. The presentation of the stimuli within each category was randomized and counterbalanced across participants. Participants were instructed to name the line drawing upon presentation, with no time pressure.

#### 2.3.2. Action naming with pictures

Participants were given two naming tasks, one consisting of single photographs (gerundial; e.g., *cutting*), the other consisting of paired photographs of actions (past tense; e.g., *chopped*). Each stimulus (single or paired) was presented one at a time, randomized and counterbalanced across participants. Participants were instructed to name each picture or picture pair using one word (e.g., *cutting*, *chopped*) that best described the action depicted in the

scene. Participants were told that only verbs should be used and that other kinds of words and phrases should be avoided. Participants were also instructed to include the proper inflection on all verbs (e.g., *-ing*), following the procedures provided by Fiez and Tranel (1997).

#### 2.3.3. Action naming with movies

Participants were presented with the 29 short movies in random order, and were instructed to name, using one word (gerundial verbs; e.g., *bouncing*), the action depicted in the scene. Participants were instructed to provide their response only once the experimenter had presented them with a question (e.g., what is the person doing?). Participants were told to avoid definitions and descriptions, and were instructed that there was no time pressure in providing their answers. Also following the instructions outlined in Fiez and Tranel's (1997) action naming task, if participants' first responses included *jumping*, *eating,* and *cutting* for movies depicting *hopping*, *tasting*, and *peeling*, respectively, they were prompted to provide a second answer (e.g., what kind of jumping? what would be a more specific word describing the action besides eating? what kind of cutting?).

### 2.4. Scoring

#### 2.4.1. Naming living and nonliving things

Based on Snodgrass and Vanderwart's (1980) norms, participants' responses were scored as correct or incorrect, receiving one point for each correctly named line drawing. In addition to the target nouns, responses considered as correct included *sofa* for *couch*, *trousers* for *pants*, *pram* for *baby carriage*, *sleigh* for *sled*, and *rat* for *mouse*. The total score for each participant was then converted into a percentage of naming accuracy.

#### 2.4.2. Action naming with pictures

On the basis of the target verbs provided in Fiez and Tranel's (1997) norms, participants' responses were scored as correct or incorrect, receiving one point for every correctly named stimulus. The total score for each participant was then converted into a percentage of naming accuracy, which comprised the raw data for analyses.

#### 2.4.3. Action naming with movies

We performed two analyses. The first was based on the Fiez and Tranel norms for the static pictures that were the basis of our movies. The scoring for this phase took into account the correct responses based on Fiez and Tranel norms for those movies that were produced following their photographs. These responses were further confirmed by a norming study with 15 healthy elderly controls who were presented with all 29 movies. Correct responses, based on controls' most frequently produced verb, were given one point, while incorrect responses were given a score of zero. The second analysis was based on weighted responses from our own norming study with 15 healthy seniors. Based on this norming data, for our secondary analysis, we calculated the proportion of each response to each token movie stimulus. For this analysis, only the items that elicited two dominant responses, which together reached a naming agreement of at least 80% of total norming responses, were kept. This resulted in 15 of the original 29 items in the task being retained for scoring. Adopting this scoring method allowed us to take into account responses that deviated from the predicted correct responses. For instance, in response to the *bouncing* movie, 12 (80%) individuals responded *bouncing* and 3 (20%) individuals responded *dribbling*. Thus, scores of .8 and .2 were given to participants who responded with the words *bouncing* and *dribbling*, respectively. Although experiment participants were instructed to produce one word that best described the action depicted in the movie, in cases where participants used more than one item that was associated with a weighted score, the highest score was attributed to the first word that the participant uttered. Additionally, responses provided in the context of a sentence (e.g., "she is *climbing up* the ladder"), despite instructions for producing one word only, were also scored as correct. If participants responded anything other than the responses gathered through the norming data, they were attributed a score of zero. The total score for each participant, for each verb category, was then converted into a percentage of naming accuracy.

## 3. Results

We relied on two data-analytic methods. First, we report repeated-measures ANOVAs, together with

planned comparisons. Second, we report case-series analyses, using Crawford et al's (1998) and Crawford et al's (2010)modified t-test, and Crawford and Garthwaite's (2005) Revised Standardized Difference Test (RSDT). The modified t-test was used to determine whether pAD individuals displayed a deficit in each of the tasks by comparing individual patient's scores to those of the control sample. We also used the RSDT to test for the presence of a dissociation by comparing pAD individuals' performance on two tasks to that of the control group. These methods reduce the rate of Type I error by treating the control sample as a sample statistic, rather than a population parameter (Crawford & Howell, 1998; Crawford & Garthwaite, 2005). Furthermore, case-series analyses allow us to draw inferences on the nature of the normal cognitive systems from different as well as similar patterns of dissociations shown by individual participants (Caramazza, 1984, 1986). For all results of the case-series analyses, see Appendix 3, in Supplementary Materials.

## 3.1. Naming living and nonliving things

### 3.1.1. Group analyses

For these analyses, after the 108 experimental items were run, we considered only the 46 living and 45 nonliving items that matched overall in all five stimuli properties in the Snodgrass and Vanderwart's (1980) norms. This more stringent criterion included naming agreement ($F$ (1, 90) = .15, $p$ = .70), familiarity ($F$ (1, 90) = 3.64, $p$ = .06), image agreement ($F$ (1, 90) = 1.89, $p$ = .17), visual complexity ($F$ (1, 90) = .01, $p$ = .91), and lexical frequency ($F$ (1, 87) = .08, $p$ = .79). See Appendix 1, in Supplementary Materials, for items employed in the experiment and for items removed in each category. After balancing the items, a 2 (group: pAD, controls) by 2 (semantic category: living, nonliving) mixed ANOVA revealed a statistically significant main effect of group, $F$(1, 19) = 50.96, $p$ = .000, $\eta_p^2$ = .728, a statistically significant main effect of semantic category, $F$(1, 19) = 5.07, $p$ = .036, $\eta_p^2$ = .211, and a statistically significant interaction between group and semantic category, $F$(1, 19) = 11.54, $p$ = .003, $\eta_p^2$ = .378. Figure 2 depicts the mean correct naming for living and nonliving categories for both groups. Overall, pAD individuals had significantly more naming difficulties than healthy controls, regardless of semantic category. Two one-way within subjects ANOVA's were then conducted to determine the locus of the significant interaction. The results revealed a statistically significant effect of semantic category for the pAD group, $F$(1, 9) = 7.83, $p$ = .021, $\eta_p^2$ = .465, indicating that pAD individuals had more difficulty naming living things. The same analysis conducted with controls revealed a marginally significant effect of semantic category, $F$(1, 10) = 4.61, $p$ = .057, $\eta_p^2$ = .315; however, indicating more difficulty naming nonliving things.[8]

### 3.1.2. Case-series analyses

An examination of each pAD individual's performance for living and nonliving categories revealed that all were significantly impaired in naming living things compared to controls. Also, as can be seen in Table 3, with the exception of two pAD individuals (P004 and P006) all others were significantly worse naming nonliving things than controls. In addition, 7 out of 10 pAD individuals showed a living/nonliving dissociation, with significantly worse performance naming living things. Overall, while inconsistent as in other studies (e.g., Laws & Sartori, 2005), these data suggest that the pAD group we studied shows a tendency for the classical living/nonliving category dissociation, with greater difficulty for naming living things.

## 3.2. Action naming with pictures

### 3.2.1. Group analyses

Table 3 shows the means for the different verb tense conditions for pAD. We first conducted a one-way between-subjects ANOVA, in order to determine whether pAD individuals exhibited an overall verb semantic deficit in contrast with the group of controls. Results showed a statistically significant effect of group, $F$(1, 19) = 68.71, $p$ < .0001, $\eta_p^2$ = .511, indicating that pAD individuals have an action naming deficit compared to controls. In addition, a 2 (group: pAD, controls) by 2 (verb inflection: gerundial, past tense) mixed ANOVA, comparing participants' performance on the action-naming task as a function of the single or paired pictures eliciting verbs in the gerundial (*-ing*) and past tense forms (*-ed*), respectively, showed a main effect of group, $F$(1, 19) = 87.4, $p$ < .0001, $\eta_p^2$ = .821, verb tense, $F$(1, 19) = 14.6, $p$ = .001, $\eta_p^2$ = .435, and an interaction between the two

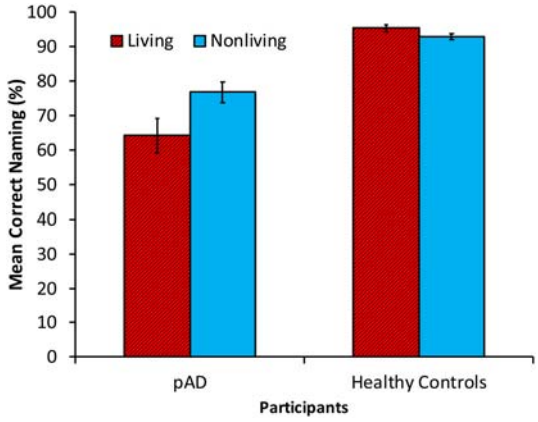


**Figure 2.** Mean percentage of correct naming as a function of semantic category (living and nonliving) and participants.

factors, $F(1, 19) = 11.2$, $p = .003$, $\eta_p^2 = .370$. Results also revealed that pAD individuals had significantly more difficulty using verbs in the past tense, compared to gerundial forms, $t\ (9) = 4.2$, $p = .002$, but there was no statistically significant difference for controls. As can be seen in Figure 3a, pAD individuals show marked difficulty for both verb forms, but more so for the regular past tense than for the gerundial form.

We were also interested in understanding the pattern of deficits with regards to the verb/noun dissociation that has been found in other studies with AD individuals as well as those with aphasia (see, e.g., Druks, 2002; and Pillon & d'Honincthun, 2010, for reviews). For this analysis, we relied on the scores for the nonliving things which was the most preserved category in the living/nonliving task. We analyzed these scores against those of the gerundial form, which relied in one-picture naming (rather than two for the past tense) and was also statistically the most preserved category among the two verb forms. Therefore, we chose to use responses from these categories because they both represented the categories with the highest naming accuracy, thus mitigating the possibility of enhancing a dissociation between nouns and verbs. A 2 (group: pAD, controls) by 2 (semantic category: object/nouns, actions/verbs) mixed ANOVA revealed a statistically significant main effect of group, $F(1, 19) = 166.04$, $p < .001$, $\eta_p^2 = .897$, with pAD individuals scoring lower overall in both categories (objects and actions), a main effect of category, $F(1, 19) = 26.40$, $p < .001$, $\eta_p^2 = .582$, with lower scores for actions than for objects, and an interaction between factors, $F(1, 19) = 10.63$, $p < .0001$, $\eta_p^2 = .359$ (see Figure 3b). Two one-way within-subjects ANOVAs were then conducted to determine the source of the significant interaction. Results showed a significant effect of category for both pAD individuals, $F(1, 9) = 17.84$, $p = .000$, $\eta_p^2 = .665$, and controls, $F(1, 10) = 9.20$, $p = .013$, $\eta_p^2 = .479$, indicating that both groups had more difficulty naming actions compared to objects. Despite the significant difference between nouns and verbs obtained for the controls, as can be seen in Figure 3b, pAD individuals responded correctly to only about half of the depicted actions, compared to controls' near ceiling performance.

### 3.2.1. Case-series analyses

Similar to the group analyses, the case-series analyses revealed that all patients were significantly impaired in naming both the single (gerundial) and the

**Table 3.** pAD individuals' correct naming (percentage) in the Object Naming and Action Naming tasks, and their dissociations.

| | Object Naming | | Object Naming Dissociation | | | Action Naming (Pictures) | | Action Naming Dissociation | | | Object-Action Dissociation+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pAD Individual | Living | Nonliving | Living Deficit | Nonliving Deficit | Living > Nonliving | Gerundial | Past Tense | Gerundial Deficit | Past Tense Deficit | Past Tense > Gerundial | Action > Object |
| P001 | 58 | 75 | * | * | * | 36 | 28 | * | * | * | * |
| P002 | 57 | 71 | * | * | * | 47 | 24 | * | * | * | – |
| P003 | 66 | 84 | * | * | * | 63 | 52 | * | * | * | – |
| P004 | 85 | 89 | * | – | – | 69 | 60 | * | * | * | – |
| P005 | 53 | 62 | * | * | * | 20 | 12 | * | * | * | – |
| P006 | 70 | 91 | * | – | * | 52 | 56 | * | * | – | * |
| P007 | 30 | 75 | * | * | * | 55 | 32 | * | * | * | – |
| P008 | 72 | 80 | * | * | * | 51 | 48 | * | * | – | – |
| P009 | 72 | 65 | * | * | – | 41 | 24 | * | * | * | * |
| P010 | 79 | 76 | * | * | – | 59 | 44 | * | * | * | – |
| *Mean* | 64 | 77 | | | | 49 | 38 | | | | |
| (*SD*) | (16) | (9) | | | | (14) | (16) | | | | |

> Denotes greater impairment.
* Denotes a significant deficit or dissociation ($\alpha = 0.05$) between categories compared to controls.
+ Contrast based on the Nonliving category task from Snodgrass and Vanderwart's (1980) pictures and the Gerundial one-picture action naming task from Fiez and Tranel (1997).

paired pictures (past tense). As can be seen in Table 3, 8 pAD individuals showed a dissociation in verb tense, with greater difficulty using the past tense. Overall, while all patients are impaired for the two verb tenses, past tense is the most affected. Results for the action/object dissociation analysis, on the other hand, revealed that only 3 out of 10 pAD individuals showed significantly more difficulty naming actions compared to objects.

### 3.3. Action naming with movies

#### 3.3.1. Group analyses

For this, our main task, we were interested in the pattern of responses that occurred as a function of verb semantic/syntactic class. Recall that our prediction was that verbs deemed more complex structurally or semantically would be the hardest to elicit. We evaluated complexity based on three hypothetical (though non-mutually exclusive) levels of representation: argument structure, thematic structure/hierarchy, and semantic template. The argument structure prediction was based on the argument-structure complexity hypothesis (ASC; e.g., Thompson, 2003). Thematic structure and thematic hierarchy (which overlap with ASC in significant ways) relies on the mapping between thematic roles and arguments assigned to canonical positions (e.g., *Agent* to the Subject position). If, however, verbs are represented in terms of the predicates that by hypothesis they share within their semantic templates, we predicted that a loss of template constituents would signal a loss of verb meaning on the assumption that these predicates are *necessary* constituents of verb meanings. In order to investigate these predictions, we first conducted a 2 (group: pAD, controls) by 3 (verb category: causative, perception, and movement verbs) mixed ANOVA to determine whether pAD individuals exhibited an overall verb semantic deficit

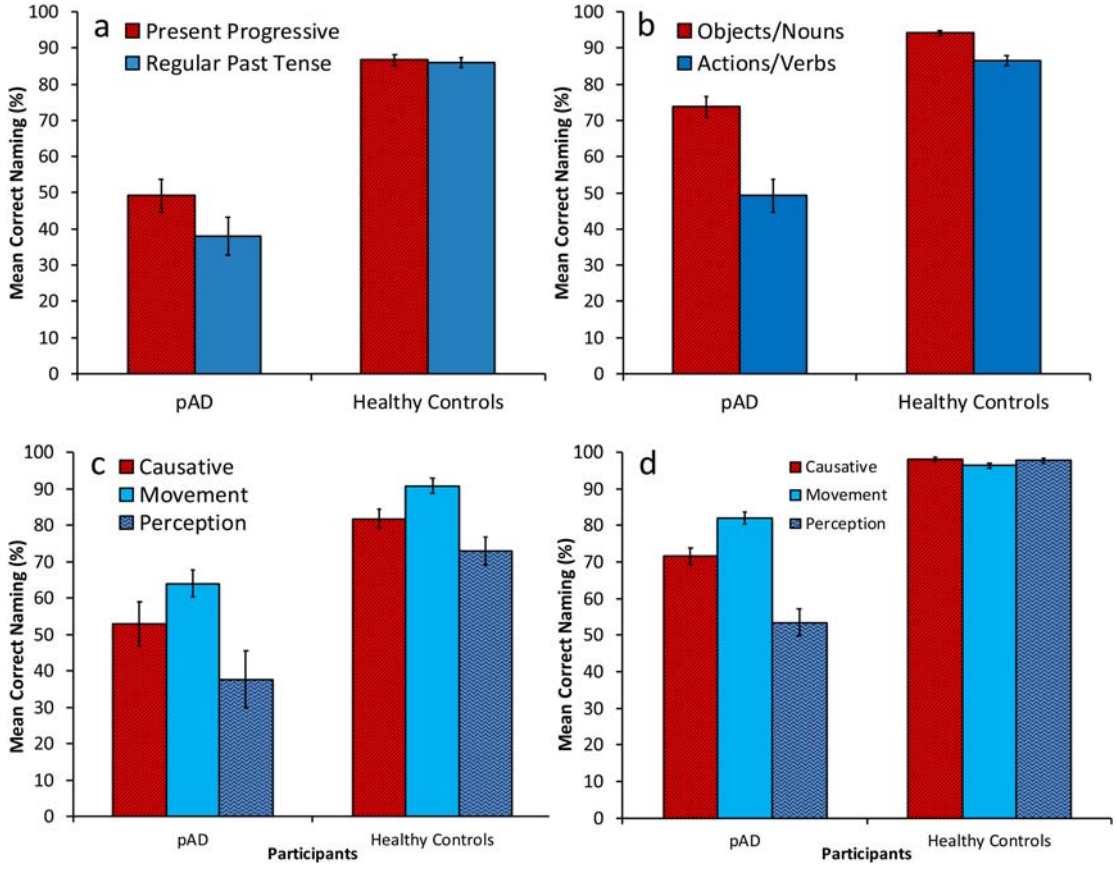


**Figure 3.** (a) Mean correct naming (%) of static events as a function of verb tense (gerundial and regular past-tense) by participant group. (b) Mean percentage of correct naming of pictures of objects and actions as a function of grammatical category (verbs x nouns) and group. (c) Mean percentage of correct action naming for movies of events as a function of verb class and group. (d) Mean percentage of correct dynamic action naming for high-naming agreement stimuli. Error bars represent standard errors.

when employing dynamic stimuli. The analyses showed a significant main effect of group, $F(1, 19) = 32.54$, $p < .001$, $\eta_p^2 = .631$, and an effect of verb category, $F(2, 38) = 18.53$, $p < .001$, $\eta_p^2 = .494$, but no significant interaction, indicating that individuals with pAD had significantly more naming difficulties than healthy controls across all verb types (see Figure 3c).

A one-way within-subjects ANOVA revealed a statistically significant effect of verb type for pAD individuals, $F(2, 18) = 8.57$, $p = .001$, $\eta_p^2 = .488$. Multiple paired comparisons yielded a marginal difference between causatives and movement verbs ($t$ (9) = −1.91, $p = .09$), a significant difference between causatives and perception verbs ($t$ (9) = 2.50, $p = .03$), and between movement and perception verbs ($t$ (9) = 3.50, $p = .007$). Using Tukey's, only the difference between movement ($M = 60$, $SD = 14.14$) and perception verbs ($M = 36.67$, $SD = 26.22$) was significant ($p = .009$). The same analyses for controls also revealed a significant effect of verb type, $F(2, 20) = 10.79$, $p = .001$, $\eta_p^2 = .519$, with a significant mean difference between movement verbs ($M = 90.91$, $SD = 7.00$) and perception verbs ($M = 72.91$ $SD = 12.64$). Further, a one-way between subjects ANOVA showed a statistically significant difference in naming accuracy between pAD individuals and controls for lexical causatives, $F(1, 19) = 20.80$, $p = .0002$, movement verbs, $F(1, 19) = 41.50$, $p < .001$, and perception verbs, $F(1, 19) = 16.78$, $p = .001$.

***3.3.1.1. Re-analyses of high naming agreement stimuli.*** In order to determine whether or not the dynamic action naming results were a function of discrepancies in action naming agreement, we then conducted a 2 (groups) by 3 (verb semantic category) mixed ANOVA based on the normed data derived from a subset of -movies – namely, for those whose naming agreement was 80% or more for the two most frequent responses. The results revealed a main effect of participants, $F(1, 19) = 23.61$, $p < .001$, $\eta_p^2 = .554$, a marginal effect of verb class, $F(2, 38) = 2.95$, $p = .064$, $\eta_p^2 = .165$, as well as a significant interaction between the two variables, $F(2, 38) = 3.47$, $p = .041$, $\eta_p^2 = .188$. As expected, the pAD group performed worse than controls in all verb classes (lexical causatives: $F(1, 19) = 14.74$, $p = .001$, $\eta_p^2 = .561$; movement verbs: $F(1, 19) = 13.79$, $p = .001$, $\eta_p^2 = .526$; and perception verbs, $F(1, 19) = 13.68$, $p = .002$, $\eta_p^2 = .511$). Given the effect size of those contrasts, the marginal differences in naming between verb classes within the pAD group ($F$ (2, 18) = 3.25, $p = .06$, $\eta_p^2 = .265$), but not within the control group, seem to suggest a category-specific deficit. Tukey's tests for comparisons between verb classes within the pAD sample showed a significant mean difference between movement verbs ($M = 78.33$, $SD = 13.72$), and perception verbs ($M = 52.50$, $SD = 39.88$), $p = .05$, $d = 2.20$ (see Figure 3d). Notice that this pattern occurs after norming data is taken into account, with control data being at ceiling. Thus, this differential performance for perception verbs cannot be attributed to their greater difficulty – as our previous analyses seem to suggest. However, the present effect should be seen with caution. One reason is that the number of items is about half of those employed in the task. Moreover, as pointed out by Laws et al. (2005), comparing healthy controls' ceiling performance against that of clinical groups increases the possibility of finding category-specific deficits. The present analysis, however, is consistent with the previous one involving all materials, suggesting that overall pAD individuals are impaired in all verb classes but show more pronounced impairment for perception (/*Experiencer*) verbs.

***3.3.1.2. Comparison between dynamic and static stimuli.*** We further analyzed the performance of pAD individuals in the present task involving dynamic stimuli with their performance in the Fiez and Tranel static stimuli. One of the hypotheses driving the present study was that dynamic stimuli would better capture verb meaning, for the interaction between agents and objects – in the case of causatives – or the temporal dynamics of event/states depicted in motion pictures, would at least in part offset the difficulty that pAD individuals would have producing verbs (and, we assume, understanding depicted events/states). For this comparison, we ran a 2 (groups) by 2 (stimuli: coloured photographs, movies) mixed ANOVA comparing naming accuracy between dynamic and static stimuli. The data for this analysis were the mean per subject in each of the two tasks (i.e., the gerundial, for the static stimuli, and the mean of the three verb classes with high naming agreement, for the dynamic stimuli). Results revealed a statistically significant main effect of group, $F(1, 19) = 89.61$, $p < .001$, $\eta_p^2 = .825$, a main

effect of stimuli, $F(1, 19) = 11.71$, $p = .003$, $\eta_p^2 = .381$, but no significant interaction, suggesting that dynamic stimuli are better at depicting events. These results are at odds with studies that found no differences between both types of stimuli in different populations (Tranel et al., 2008). However, it is important to note that we did not compare the same verbs across tasks, which could have been more appropriate for investigating this hypothesis. Rather, we set aside causatives, movement, and perception verbs from Fiez and Tranel's task to develop our dynamic stimuli, for we did not want participants to be exposed twice to the same events/states. Moreover, the resulting static-stimuli set, against which we compared our stimuli, could not be classified into coherent semantic classes which could have yielded a more accurate analysis across tasks. Thus, the results of this comparison should be seen with caution. However, we can argue that motion pictures can be used as a more ecologically valid form for depicting verbs in tasks that require patients to understand the temporal properties of events and states – that is, how they unfold over time. In addition, these stimuli can be used to probe other kinds of knowledge supposedly encoded in verbs, such as predicting the resulting state of an object or the path of a body in motion – which might be difficult to infer from static pictures.

### 3.3.2. Case-series analyses

Results of the case-series analyses are shown in Table 4 (see also Appendix 3, in Supplementary Materials, for full statistical analyses). These results revealed that 8 out of 10 pAD individuals showed a deficit for naming causative actions, 8 out of 10 for naming movement actions, and 6 out of 10 for naming perception events. Similarly, 6 out of 10 pAD individuals were significantly more impaired in naming perception events compared to causatives. Of these, half of the pAD individuals had greater difficulty naming perception events, and the other half had greater difficulty naming causative actions. However, only 2 out of 10 pAD individuals were significantly more impaired in movement actions compared to perception events, and one pAD individual was more impaired in naming perception events compared to movement actions. Notice, however, that these observations do not take into account naming agreement, which we address in the next section.

#### 3.3.2.1. Re-analyses of high naming agreement stimuli.

As can be seen in Table 5, similar to the ANOVA results, case-series analyses revealed that 8 out of 10 pAD individuals showed an action-naming deficit for causative verbs, 5 out of 10 for movement verbs, and 8 out of 10 for perception verbs. Results also showed that 2 out of 10 pAD individuals were significantly more impaired in naming causative verbs compared to movement verbs, 4 out of 10 for naming perception verbs compared to causative verbs, 3 out of 10 for naming causative verbs compared to perception verbs, 6 out of 10 for naming perception verbs compared to movement verbs, and only 1 out of 10 for naming movement verbs compared to perception verbs.

Taken together, these observations show a greater pattern of impairment for causative and perception verbs. What binds these two classes together is their similar argument structures, with both licensing two arguments. However, this effect is not consistent when we contrast *between* verb classes. In these contrasts, perception verbs are worse than movement verbs, as expected. Conversely, the same deficit – with greater impairment for causatives compared to movement verbs – was not found. When we contrast perception and causative verbs, which are the two verb classes with more complex argument structures, the data show that there is a trend for perception verbs being more impaired than causatives. What can perhaps account for this inconsistency lies above the level of argument structure (see Table 1): thematic roles, as determined by thematic hierarchy, with perception verbs deviating from canonical order (viz., *Experiencer* rather than *Agent*). The heterogeneity of patient performance across verb classes is further addressed in the General Discussion.

#### 3.3.2.2 Comparison between dynamic and static stimuli.

When further analyzing the individual performance of pAD's in the action naming tasks by comparing responses obtained from dynamic and static stimuli, results revealed that all patients were significantly impaired in naming actions elicited through static stimuli, and 9 out of 10 pAD individuals for

**Table 4.** pAD individuals' correct naming (percentage) in the Dynamic Action Naming task and its dissociations.

| | Dynamic Action Naming | | | Dynamic Action Naming Dissociations | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| pAD Individual | Causative | Movement | Perception | Causative Deficit | Movement Deficit | Perception Deficit | Causative v. Movement | Perception v. Causative | Movement v. Perception |
| P001 | 10 | 40 | 0 | * | * | * | – | > | – |
| P002 | 50 | 50 | 0 | * | * | * | – | > | – |
| P003 | 70 | 80 | 44 | – | * | * | – | – | – |
| P004 | 80 | 70 | 44 | – | – | * | – | > | – |
| P005 | 40 | 50 | 0 | * | * | * | – | – | – |
| P006 | 60 | 60 | 56 | * | * | – | – | – | < |
| P007 | 60 | 80 | 67 | * | – | – | – | < | – |
| P008 | 50 | 50 | 56 | * | * | – | – | – | – |
| P009 | 60 | 70 | 44 | * | * | * | – | > | – |
| P010 | 50 | 50 | 56 | * | * | – | – | < | > |
| *Mean* | 53 | 60 | 37 | | | | | | |
| (*SD*) | (19) | (14) | (26) | | | | | | |

> Denotes greater impairment.
* Denotes a significant deficit ($\alpha = 0.05$) compared to controls.

actions depicted through dynamic stimuli. Furthermore, results also showed that 4 out of 10 pAD individuals were significantly more impaired in naming actions when presented in static scenes, while no pAD individuals showed greater impairment for dynamic stimuli compared to static ones (see Table 6). These results are further validated by a study employing the visual-world paradigm showing that dynamic scenes yield different results compared to static scenes (de Almeida et al., 2019), suggesting that dynamic scenes better represent the dynamics of actions and events.

## 4. General discussion

The main goal of the present study was to determine whether individuals with pAD would show category-specific deficits for concepts that are labelled by verbs, as has been demonstrated for other types of concepts. Moreover, we were interested in determining the types of representations upon which verb categories might be impaired. We did so primarily by employing a dynamic action naming task involving three classes of verbs – causatives, perception/psychological, and movement. Besides naming different events and states, these verb classes also differ with regards to their linguistic-structural and conceptual properties. We operationalized our contrasts based on argument structure, thematic roles, and semantic/conceptual templates by which these verbs might be hypothetically represented. We also reasoned that most verbs denote dynamic events and states, and thus would be best conveyed through dynamic stimuli, such as realistic short-movies of actions (Fung et al., 2001). While previous studies investigating verb knowledge impairments

**Table 5.** pAD individuals' correct naming (percentage) in the Dynamic Action Naming task and its dissociations with high naming-agreement stimuli.

| | Dynamic Action Naming (High Naming Agreement Movies) | | | Dynamic Action Naming Dissociations (High Naming Agreement Movies) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| pAD Individual | Causative | Movement | Perception | Causative Deficit | Movement Deficit | Perception Deficit | Causative v. Movement | Perception v. Causative | Movement v. Perception |
| P001 | 20 | 67 | 0 | * | * | * | > | – | < |
| P002 | 80 | 67 | 0 | * | * | * | – | > | < |
| P003 | 60 | 100 | 75 | * | – | * | > | < | < |
| P004 | 100 | 83 | 100 | – | – | – | – | – | – |
| P005 | 60 | 67 | 0 | * | * | * | – | > | < |
| P006 | 80 | 83 | 50 | * | – | * | – | > | < |
| P007 | 100 | 100 | 50 | – | – | * | – | > | < |
| P008 | 60 | 67 | 100 | * | * | – | – | < | > |
| P009 | 80 | 83 | 75 | * | – | * | – | – | – |
| P010 | 60 | 67 | 75 | * | * | * | – | < | > |
| *Mean* | 70 | 78 | 53 | | | | | | |
| (*SD*) | (24) | (14) | (40) | | | | | | |

> Denotes greater impairment.
* Denotes a significant dissociation ($\alpha = 0.05$) between categories compared to controls.

**Table 6.** Comparison between Action Naming stimuli type.

| | Static v. Dynamic Action Naming Deficit | | |
|---|---|---|---|
| pAD Individual | Static Scenes | Dynamic Scenes | Static v. Dynamic |
| P001 | * | * | – |
| P002 | * | * | – |
| P003 | * | * | – |
| P004 | * | – | – |
| P005 | * | * | > |
| P006 | * | * | – |
| P007 | * | * | > |
| P008 | * | * | > |
| P009 | * | * | > |
| P010 | * | * | – |

> Denotes greater impairment.
* Denotes a significant dissociation (α = 0.05) between categories compared to controls.

in Alzheimer's have employed static stimuli, such as coloured photographs or line drawings (e.g., Kim & Thompson, 2004) to depict verb concepts, to our knowledge the present study is the first to employ realistic video clips of actions to investigate verb representations and, in particular, whether or not individuals with pAD show *category-specific* verb deficits.

We obtained results that are consistent with the hypothesis that AD individuals have semantic deficits affecting particular categories of knowledge. In our first task, employing a living/nonliving object naming task, we found that pAD individuals have greater difficulty naming living things, thus replicating an effect found in numerous other studies (e.g., Laws, Crawford, et al., 2007; Moss et al., 2002; Silveri et al., 1991; Whatmough & Chertkow, 2002; Zannino et al., 2007). The pattern of dissociation we found, however, is quite limited to naming line drawings representing a variety of categories of living and nonliving things. A meta-analysis by Laws, Adlington, et al. (2007) found that the living/nonliving dissociation is subject to variables that we did not control for, such as gender, due to our relatively small sample size. Nonetheless we matched Snodgrass and Vanderwart's stimuli on several variables that Laws, Adlington, et al. (2007) take to be the most important to control for spurious effects in naming tasks. The majority of our pAD sample (8/10) showed a living things compared to nonliving things deficit, a pattern that was significant within subjects and compared to controls. Whether or not this effect overall reflects a category-specific deficit we cannot determine. For one, category-specificity along the living/nonliving divide would require us to test the pAD group using other tasks, such as word-picture matching, definitions, as well as other modalities, which often show different results (Pillon & d'Honincthun, 2010). We assume, however, that the results are indicative of a pattern of dissociation found in other studies, which suggest greater semantic impairment in living things.

Our second task, involving pictures of events and states (Fiez & Tranel, 1997), had two goals: first, we wanted to test for a potential verb/noun dissociation and, second, we were interested in the pattern of performance of pAD individuals concerning verbs depicted in realistic (although static) scenes. We have obtained both, a verb deficit (compared to the control group) as well as a verb/noun dissociation, suggesting greater difficulty naming events and states in AD relative to object concepts, which is also consistent with other studies (e.g., Cappa et al., 1998). Whether or not the verb/noun dissociation represents a dissociation between *concepts* that are lexicalized by nouns and verbs is yet to be determined. Chertkow and Bub (1990), have argued persuasively that naming errors reveal a *semantic* deficit in AD, rather than a perceptual or lexical deficit. We thus argue that a difficulty in naming is suggestive of a difficulty at the conceptual level rather than a deficit affecting either lexical retrieval or access to conceptual knowledge (for this later view, see, e.g., Bayles et al., 1990). It is interesting to note that similarly to findings by Druks and colleagues (Druks et al., 2006), the potential object/action naming dissociation we observed in the pAD group was also observed in the control group.

A more specific manifestation of the pAD group's difficulty with verbs is the dissociation found in verb tense, with significantly greater difficulty using past tense compared to gerundial. It is possible that this dissociation reflects greater difficulty accessing information about the temporal dimensions of the event. However, it is also possible that this dissociation may be due to the complexity of the task: while in the gerundial, participants have simply to name the current state of an event based on one photograph, the past tense requires inferring the current state of an object from its previous state based on two photographs. Thus, it is possible that over and above verb-retrieval difficulties, what the pAD group shows is an inferential difficulty, which could characterize a task effect. However, Kemmerer and Tranel (2000a), testing the same stimuli in a group of left-hemisphere brain damaged individuals found no statistically

significant difference between the one-picture and the two-picture sets. Thus, although task effects cannot be discarded, our results with the pAD group seems to suggest that underlying the different performance in the two tasks could be an impairment that is linguistic in nature, affecting verb tense features.

Our main goal was to investigate the nature of verb deficits by contrasting verb classes that differ along three hypothetical levels of representation: argument structure, thematic structure, and semantic template. Although there are linguistic arguments for distinguishing between these types of representation, there are also arguments for assuming that semantic templates incorporate all three levels of analysis, indeed doing away with thematic roles altogether (e.g., Levin & Rappaport Hovav, 2005). Given that the pAD group shows a marked deficit for naming living things and also a verb deficit, we sought to understand the dimensions under which verb knowledge might be organized in the brain. Our main theoretical goal was to investigate the pattern of verb deficits by manipulating different properties as a function of verb class – in particular contrasting lexical causatives with movement verbs and perception/psychological verbs.

The pattern of results we obtained however cannot be predicted by template complexity, in particular by number of internal predicates. Individuals with pAD showed greater difficulty with perception/psychological verbs which by hypothesis have one internal predicate in their templates but two arguments. Movement verbs, which also by hypothesis are represented by one predicate and license one argument, however, yielded the least amount of naming errors. Causatives, which are supposed to be represented by more complex templates in terms of number of predicates were not as affected as perception/psychological verbs. This pattern of deficits casts doubt on verb templates as the main type of representation by which verbs are categorized. Assuming concepts are clustered into categories based on shared properties, these properties do not appear to be common predicate elements in their semantic templates.

Two other types of representation, then appear as potential loci of verb categorization effects: number of arguments or thematic properties assigned to these arguments. However, the number of arguments – i.e., the syntactic information – that verbs yield cannot fully account for the pattern of results we got. As we discussed above, although the two-argument class of perception/psychological verbs yielded significantly more errors than the one-argument class of movement verbs, causatives did not differ from movement verbs. According to ASC (e.g., Thompson, 2003), number of arguments is positively associated with retrieval errors. For instance, Kim and Thompson (2004) have shown that individuals with agrammatism exhibit significantly more errors retrieving three-place verbs (e.g., *The boy is leaning the ladder against the wall*) than two-place verbs (e.g*., The girl is drying the dishes*), and significantly more errors retrieving two-place verbs than one-place verbs (e.g., *The dog is barking*). However, close examination of the verbs used in the static picture naming task in the present study indicated that among past-tense verbs, 85% included one-place (e.g., *She turned*) and 15% included two-place (e.g., *She framed the picture*) verbs. Among the verbs in the gerundial class, 42.7% were two-place (e.g., *She is kicking the ball*) and 57.3% were one-place (e.g., *She is smiling*) structures. Although our task was not designed to investigate the ASC hypothesis specifically, a greater proportion of two-place verbs in the gerundial stimuli would have hindered pAD individuals' performance with that tense, though the effect was the opposite, with worse performance in the past tense. Together with the dynamic action naming task, these results suggest that number of arguments does not seem to determine category effects in verb naming.

The pattern of results we obtained is more consistent with a thematic-roles deficit. We found that perception/psychological verbs were more severely impaired in AD, in contrast to other verb classes. As we discussed in the introduction, what makes the perception/psychological class more complex is not the number of arguments that they license but the roles assigned to these arguments. In this class, in particular, the role of *Experiencer* is assigned to the external (subject position) argument. Crucially, the events/states that these verbs name lack an agent. That is, the role assigned to participants in events/states is not that of *Agent*, as in the other verb classes we employed. According to thematic-hierarchy proposals (see de Almeida & Manouilidou, 2015, for a review), the *Agent* role is the most prominent and its absence violates canonical thematic assignment. Indeed, as

shown in a study by Manouilidou et al. (2009), as sentence frames deviate from canonical assignment (e.g., [*Experiencer, Theme*], as in *The boy fears the thunder*) pAD individuals show significant decrease in performance compared to agentive frames. Consistent with this study, our results seem to indicate greater deficit for *Experiencer* verbs than for those that assign an *Agent* to the subject position, thus constituting not only a thematic-role effect but an effect consistent with thematic-hierarchy proposals

It is important to note that this thematic-role effect was obtained only when verbs were controlled for naming agreement. It was only then that we observed an interaction between groups and verb types. Thus, it is not entirely clear whether we can generalize this effect to a *category-specific* deficit for *Experiencer* verbs. Indeed, the limited scope of verb classes and participants in our dynamic-stimuli task make it difficult to determine whether or not the deficit affects a particular type of thematic role. For one, given that our task involved specifically naming, pAD individuals' knowledge with other uses of verb information (e.g., sentence production) was not tested. Moreover, we were limited to the class of *Experiencer* verbs that we were able to depict. The psychological sub-class of *Experiencer* verbs, in particular, involves mental states that cannot be easily depicted in order to distinguish between Subject-*Experiencer* (*fear*) and Object-*Experiencer* (*frighten*), as in the task employed by Manouilidou et al. (2009).

In summary, we have proposed that verb category-specific effects were obtained and that the most likely semantic information affected was that of thematic-role assignment. We cannot, however, rule out the possibility that verb classes are represented – and consequently affected in AD – by a combination of factors. For instance, it is possible that, if templates are indeed the way verbs are represented conceptually, the pattern of deficits we obtained can be explained by the lack of the *ACT* predicate in the template of perception/psychological verbs, on the hypothesis that movement verbs do include this predicate as well, contrary to what we suggested in the Introduction (see Table 1). Under this view, it is not the number of arguments, nor the number of predicates in the template, but the lack of a particular predicate (*ACT*) in the representation of perception/psychological verbs that yields worse performance by pAD individuals. This would be in part equivalent to our proposal for a *thematic* effect, except that thematic information would be included in the template (see, e.g., Levin & Rappaport Hovav, 2005). This view however would be difficult to reconcile with the results of the Manouilidou et al. (2009) study which showed a structural-mapping effect, that is, with frames involving Object-*Experiencer* verbs being worse than Subject-*Experiencer* verbs, independent of linear order, that is, even when the sentences presented to subjects were in the passive voice (e.g, *The boy was frightened by the thunder*). A simple lack of the *ACT* predicate would not predict a difference between types of *Experiencer* verbs.

Consistent with other studies we reviewed, the present study points to a thematic-role assignment effect in naming events/states, suggesting that verbs are primarily bundled into categories grounded on the kinds of thematic roles they assign. It is important to note, however, that this may not be the only way that verb semantic information and, in particular, verb categories are organized. One reason is that if thematic roles constitute the main binding elements for verb categories, this would imply that verbs that assign the same roles to their arguments but refer to arguably different types of event referents would be clustered together. For instance, consider the verbs *kill* and *kick*. Both license two arguments and assign an *Agent* to the subject position and a *Theme/Patient* to the object position. But they arguably refer to different events such as kicking a ball and killing an insect. If all it takes for verbs to be grouped into categories is their shared thematic structures, we would have to argue that these verbs belong to the same category. While this is a possibility, it is difficult to determine a metric for their similarity without considering other levels of representation. On the other hand, Jackendoff (1990), has proposed different levels of representation upon which verbs could be said to share features or properties, in particular types of internal predicates. This view allows for numerous ways in which verbs can be said to have both a core meaning representation and at the same time be flexible with different demands of use.

Our results, however, seem to be at odds with this semantic template view. Our hypothesis relied on the idea that the loss of an internal predicate would result in a deficit for a given category. Recall that the study by Kim and Thompson (2004) found

that pAD individuals have more difficulty with light verbs (such as *go*) than with heavy verbs (such as *run*). But at the same time, they postulated a semantic template in which the predicate *GO* (supposedly the conceptual representation of the verb *go*) is part of the template of the verb *run*. We argued that the loss of *GO* would render the meaning of *run* vacuous. On the assumption that meanings are *definitions*, this would be equivalent to the meaning of *dog* being void of *CANINE*. One way to reconcile our results with those of Kim and Thompson's is to postulate that verb classes are *not* represented by complex semantic templates but by thematic structure, which is compatible with some of the results they also obtained.

There is yet another, theoretical reason for rejecting the template-complexity hypothesis: it rests on the analytic/synthetic distinction, that is, it rests on the assumption that there is a criterion for determining which features (or predicates such as *CAUSE* and *GO*) are to be constituents of the template and which ones are not – that is, which ones are *necessary* and which ones are *contingent* on experience. And thus far, to our knowledge, there is no such a criterion (see Fodor & Lepore, 2006; and de Almeida & Antal, 2020, for recent discussions). Assuming that concepts labelled by verbs are not internally complex – based on both empirical and theoretical reasons – implies a commitment to a kind of semantic atomism (de Almeida, 1999b; Fodor, 1998). This view takes conceptual relations, such as those between verbs said to belong to the same class, to be established by shared *meaning postulates*, that is, shared inferences. These postulates account for many of the flexible aspects of a verb's meaning, while leaving the core constant, without depending on an analytic/synthetic distinction. Also, several psycholinguistic experiments have failed to account for differences between hypothetically complex and simplex lexical items (e.g., de Almeida, 1999b; Fodor et al., 1980; Manouilidou & de Almeida, 2013; Mobayyen & de Almeida, 2005; Rayner & Duffy, 1986). Although the present investigation cannot distinguish between these different theoretical views it points to some venues for further investigating the nature of verb meaning and how patterns of semantic dissociation can help us evaluate the nature of verb-conceptual representation.

Finally, while the group analyses yielded a clear pattern of results, with perception verbs showing greater impairment than the other classes, we would like to address the heterogeneity of patient performance obtained in the case-series analyses. We could, in principle, attribute heterogeneity to several causes, including premorbid individual differences (e.g., cognitive and linguistic abilities), disease severity, and task performance. We base our conclusions on the majority of cases, suggesting a *trend* (Schwartz & Dell, 2010) towards the effects obtained in the group analyses. When we look at the pattern of results shown in Table 5, it is clear that causative and perception/psychological verbs are the most affected. Breaking down these patterns for a comparison between verb classes shows that it is the perception/psychological class that is most affected. This pattern suggests that the verb deficit is at the level of thematic roles (see Table 1). The tendencies found at the case-series analyses, thus, point in the same direction as the group analyses, while also providing us with rich information about the variability of performance.

It is also possible to conceive that the heterogeneity of patient performance simply reflects heterogeneity of functional lesion within the *same* general architecture, affecting different types of representations, processing levels, or components. For instance, it is possible that some patients may have a deterioration affecting more basic, structural properties of verbs – such as argument structure – while others may have higher-level difficulty computing entailments necessary to produce a response given an object or dynamic scene stimulus. Our goal throughout has been to investigate verb knowledge aiming to understand the nature of the unimpaired lexical-conceptual system and how it organizes events and states lexicalized by verbs. This view assumes that our tasks probed individuals that share a common functional architecture, with data providing us with different snapshots of the same representations, thus, in principle, against the view that heterogeneity reflects "lawful variation" (Bub, 2011) within the population.

In conclusion, we found semantic deficits in AD affecting categories labelled by nouns, in particular *living things*. Moreover, we found that pAD individuals also show a verb deficit and, more specifically, as our dynamic action naming task shows, this deficit appears to affect more certain categories of verbs. We suggest that the psychological/perception class

– a class that by hypothesis assigns an *Experiencer* role to the subjects of events/states that these verbs name – are affected in AD, consistent with previous studies (see Manouilidou et al., 2009; Manouilidou & de Almeida, 2009). We propose that thematic roles are the main "glue" upon which verbs might be represented in the brain and thus affected such as in the case of Alzheimer's. This might be so because thematic roles might serve as the main elements mapping linguistic utterances to their semantic/conceptual representations. We suggest moreover that verbs are not represented by decompositional semantic templates. Methodologically, the current study is, to our knowledge, the first to investigate verb semantic deficits in pAD individuals by employing dynamic stimuli, such as short movies of events. We have shown that pAD individuals perform better when presented with dynamic scenes depicting events and thus we highlight the importance of using ecologically valid stimuli in the investigation of verb knowledge.

## Notes

1. Although the literature on category-specific deficits usually takes the term "semantic" to refer to categories of knowledge affected in semantic memory, "semantic" may be used refer to properties of verb meanings that are "linguistically active", to use Grimshaw's (2005) expression – i.e., those that affect linguistic *structure*. The term "conceptual" or "concepts" is usually taken to refer to the units of higher cognitive representation and processing, independent of their linguistic implementation. We will make this distinction, where context makes it necessary. But, for the most part, we will use "semantic" and "conceptual" interchangeably, with both referring to word meanings as well as to the units of semantic memory.
2. Some authors (e.g., Levin & Rappaport Hovav, 2005) take these predicates to specify *subevents* in the whole event denoted by the verb and its carrier sentence. For instance, (1) implies two subevents – that the agent *x* did something, and that the object *y* changed its state. We will avoid a detailed discussion of this theory, but address the nature of predicate decomposition in the General Discussion.
3. It is possible that this hierarchy implies a form of redundant representation: that, say, *GO* is represented redundantly at possibly all three levels – it is a *feature*, in Kim and Thompson's (2004) account. Thus, losing *GO* means losing its associated superordinate verbs (*go*, perhaps), but not other levels of representation which incorporate or inherit the feature/predicate *GO* (e.g., *run*). This "redundancy" hypothesis, however, raises numerous questions about the nature of the representation of concepts that is postulated and how concepts might be affected selectively. It implies, for instance, that *GO* is affected at the top level but continues to contribute content to lower-level verbs. If that is not the case, it remains to be explained how a concept can have a feature such as *GO* without other concepts also incorporating its content – including the meaning of the verb *go* itself.
4. This analysis is restricted to this example. Although Grossman and White-Devine (1998) used 60 causatives, it is not clear how many of those are *morphological causatives* (that is, overtly marked by morphemes such as *-en* and *-ify*) rather than *lexical* causatives.
5. Henceforth, we will refer to this class as *perception*, though recognizing that many verbs within this class can be taken as agentive and that the *psychological* class can sometimes be analyzed as causative (e.g., Pesetsky, 1995). In the present investigation, only *Subject-Experiencer* verbs were employed (see Manouilidou & de Almeida, 2009, for discussion).
6. Notice that the causative verbs we used can also be inchoatives (one argument), thus they could, in principle, be easier than perception/psychological verbs. However, our stimuli and task are setup in a way that requires an agentive interpretation of causatives, thus yielding a transitive interpretation.
7. We recognize that the use of the NINCDS-ADRDA is a potential limitation of our study, given newer diagnosis criteria (Dubois et al., 2007; McKhann et al., 2011). However, we should note that our pAD sample was selected based on a battery of clinical and neurocognitive assessments, in addition to the NINCDS-ADRDA.
8. It should be noted that, as shown by several studies (see Capitani et al., 2003, for review), musical instruments usually pattern with living things, and body parts, with nonliving things. Although it is not the main scope of the present study to investigate subcategories of living and nonliving categories, our results show a similar pattern, with body parts being significantly better than other living subcategories, and musical instruments being significantly worse than other nonliving subcategories. Removing these items did not change the nature of the dissociation we obtained.

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