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FEATURE ARTICLE

In search of Noun-Verb dissociations in aphasia across three processing tasks

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IN SEARCH OF NOUN-VERB DISSOCIATIONS IN APHASIA ACROSS THREE PROCESSING TASKS

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Abstract

This paper presents work we conducted in our search to understand how the brain is organized for meaning (both linguistic and non-linguistic). We address the notion of noun-verb dissociations, which has often been studied but remains controversial. We tested a group of 21 patients with aphasia (Anomic, Broca and Wernicke) along with a group of 20 college-aged and older control participants on a word production battery which counterbalanced noun and verb stimuli across three popular word-processing tasks: picture-naming (PN), word reading and repetition (WRP, or word repetition paradigm). Several important variables were controlled for during item selection and in post-hoc analyses, e.g., word frequency, age of acquisition, naming difficulty and ambiguity, among others. Results revealed that PN was the most difficult task across groups, and also the only condition in which any significant noun-verb differences were observed (contrary to similar studies using blocked noun-only or verb-only stimuli). In addition, all groups displayed a noun advantage (commonly seen for healthy participants and contrary to the notion of a verb advantage in certain brain-injured groups). These noun-verb results, acquired with a flexible, highly applicable stimuli set, set the stage for subsequent analyses focusing on deeper, sensorimotor-based distinctions in language processing.

Introduction

Over the years, several investigators have explored the notion that nouns and verbs differ on a number of syntactic and semantic levels. Whereas nouns (objects) represent items one can readily identify in one's environment (at least in the case of concrete nouns), verbs (actions) tend to represent events which may occur over time and may thus be more difficult to convey in a simple way, such as with static picture stimuli. Actions may also carry the added weight of transitivity: the depiction of transitive verbs may require the presentation of multiple items necessary to adequately depict the action, thus increasing the complexity of their visual presentation and the time needed for their processing.

Various studies have revealed differences in the acquisition, processing and breakdown of nouns and verbs. In developmental research, the semantic structures underlying verbs have been argued to be more complex and open-ended (Gentner, 1982), and at least in English, verbs seem to appear in a child's lexicon only after a considerable vocabulary expansion of approximately two-hundred words has taken place (Bates et al., 1988). In addition, a double-dissociation between noun and verb processing has been observed in brain-injured patients across several languages (Chen & Bates, 1998; Daniele et al., 1994; Zingeser & Berndt, 1990): previous research has suggested that while Wernicke's patients and some Anomic patients display more severe problems processing nouns than verbs, non-fluent Broca's patients display more deficits in verb processing.

Classic teaching is not reliably replicated, however. One problem with many study designs is the way in which "good" vs. "bad" performance is defined without providing clear, statistically-determined evaluations. Many studies also suffer from small sample sizes (indeed, the majority are single case reports). Therefore, predicting performance profiles from conventional (or classic) taxonomies remains largely unreliable.

Whether dissociations lie along syntactic or semantic lines also remains controversial, despite the fact that the noun-verb dissociation is one of the most studied phenomena in semantic processing. One theory argues that the two word categories dissociate along lexical lines and that each is processed in a separate cortical area (Caramazza & Hillis, 1991; Shapiro et al., 2001). Others have suggested that items are organized not by grammatical class but by their semantic and physical features and the correlations between these (Allport, 1985; Martin & Chao, 2001). Finally, yet another theory proposes that noun-verb distinctions may reflect broader, sensorimotor meaning differences underlying the two categories, and while noun processing is associated with posterior, sensory cortical areas, verb processing is associated with anterior motor areas (Pulvermüller, 1996).

In addition, studies using various imaging techniques such as ERP and PET have suggested the involvement of distinct brain regions in the processing of nouns and verbs (Perani et al., 1999; Molfese et al., 1996). However, no study has convincingly shown that nouns and verbs, respectively, activate separate and discrete cortical areas. Mostly, these studies have revealed areas activated more by one category over the other, and those that have claimed to find discrete noun and discrete verb areas (i.e., a neurological double-dissociation, e.g. Pulvermüller, 1996) have used techniques with poorer spatial resolution (i.e., ERP), thus limiting the results' credibility.

Finally, Luzzatti et al. (2002) have argued that dissociations cannot be taken as proof that nouns and verbs are stored in anatomically and functionally distinct mental lexicons. These authors suggest that noun-verb differences depend strongly on specific features underlying each concept (e.g., word frequency and imageability), both at the lemma and semantic levels. Jonkers and Bastiaanse (1998) further suggest that once such factors are adequately controlled for, verbs and nouns dissociate in one direction only, with all aphasic patients displaying greater difficulty with verb relative to noun retrieval. In this work we controlled for a list of such variables (see Picture-naming (PN), word reading & word repetition paradigm (WRP) below). When possible, we matched the two word categories on such variables during item selection; when matching became difficult or virtually impossible, we conducted post-hoc analyses in order to ensure that these variables were not a significant cause of groups' performance differences on the two categories.

In addition, intrinsic to these stimuli and particularly important for the PN task is naming ambiguity. As mentioned above, one variable which adds to the conceptual discrepancies between action and object concepts is the depiction of actions in a 2-D static format. This and other factors most likely lead to greater variability in the way individuals respond to action vs. object pictures in the PN task. In fact, in this study, a higher proportion of alternative answers were consistently produced for actions relative to objects. We also took this fact into consideration when scoring participants' responses, accepting various alternative answers as correct. Of course, this does not control for the probability that many alternative answers (caused by more ambiguous pictures, usually actions) are simply incorrect, since not all interpretations of an ambiguous picture can be equally acceptable. Therefore, ambiguity is a variable which we accounted for wherever possible, and which we address in our discussions as an important factor in the present study and studies using similar stimuli and tasks

Picture-naming (PN), word reading & word repetition paradigm (WRP)

Over the years, experimenters have used various processing tasks to test participants' production and comprehension of different syntactic/ semantic concepts, such as nouns and verbs. In our work, we have chosen to test participants' production abilities on three of these: PN (picture-naming), single word reading and WRP (word repetition paradigm). These tasks require very different processing abilities and involve two different sensory modalities: visual and auditory.

The first task mentioned, PN, is among the first paradigms ever used to study real-time language processing (Székely et al., 2003). In order to name a picture, one must recognize a particular concept from an image, derive its specific meaning, and link that meaning to its appropriate label, which in turn must be produced. Various different models have been proposed to account for our ability to perform such a task, each with its own set of processing stages. One such model is that suggested by Johnson et al. (1996), which includes a minimum of three universal stages: (1) analysis and recognition of the object or event being depicted, (2) retrieval of the word form(s) that express the object and selection of the preferred name, and (3) planning and execution of the selected name (see also Levelt's model: Levelt, Roelofs & Meyer, 1999; Levelt, 1989).

Reading and WRP, on the other hand, most likely involve quite different types of processing. WRP varies from the other two tasks in that it is purely auditory. Thus, performance on WRP should be significantly influenced by word-form properties manifested at the spoken level, such as word length and initial letter sound. Reading should similarly be affected by such word-form properties when these are manifested visually (e.g., word length). Finally, PN, while also visual, is strongly dependent on semantic properties, since this task (arguably more so than the other two) requires one to process the meaning behind the image in order to produce the appropriate response. Other factors considered to be particularly important for PN are "goodness of depiction" of the pictures used, word frequency of their corresponding written or spoken forms and age of acquisition (these last two have also been found to influence reading, Bates et al., 2001).

As discussed below (see Materials & Background), matching object and action items on a series of variables considered crucial for their processing is a highly difficult task. Therefore, wherever we were not able to provide a tight match between word categories on a particular variable, we performed post-hoc analyses to determine whether the difference in values between the categories had a significant influence on the way these were processed by the different participant groups. This was not the case for any of the six variables: objective visual complexity (of the picture form), and word frequency, age of acquisition, number of syllables, number of characters (i.e., word length), and initial letter frication (of the written or spoken form of each item). Finally, as mentioned above (see Introduction), we considered naming ambiguity as another important variable influencing naming difficulty of action vs. object pictures (PN). We controlled for this variable as much as possible by considering various alternative answers as correct whenever appropriate and discussing the role of ambiguity in our results.

Materials & Background

The stimuli used in this study are part of the CRL-IPNP (the Center for Research in Language International Picture-Naming Project, Bates et al., 2000), a large corpus of noun and verb pictures (all 2-D black-and-white line drawings, 275 depicting actions and 520 depicting objects) which was developed in our lab and has had various applications over the last few years. Thus far, our colleagues around the world have tested these stimuli on participants in different age groups and across seven different languages. For each language, each picture was assigned its own target name, which was the name produced by the largest number of participants for that picture (on norming runs with healthy adult native speakers). The target names were then used to create the reading and WRP paradigms: for reading runs, target words are presented in written form one at a time on the computer screen, while for WRP, the screen is blank and target words are aurally presented in isolation.

One major advantage of our stimuli set is that it allows us to selectively alternate our focus and simultaneously test many different categorical distinctions. Namely, stimuli can be analyzed along the lexical distinction (nouns vs. verbs), along semantic distinctions (nouns and verbs representing action vs. object concepts) and along different sesorimotor meaning representations (e.g., manipulability, as will be discussed in future work). Thus, for the current study we began by looking at the most common distinction, that of nouns vs. verbs.

Testing our stimuli across three different processing tasks (which recruit two different sensory modalities) allows us to further challenge these putative dissociations. For example, evidence for a dissociation along lexical lines would emerge if significant noun-verb differences were manifested across all three conditions. On the other hand, dissociations occurring in only one condition would constitute weak evidence for the lexical view and would compel us to seek other ways in which these concepts might dissociate.

As mentioned above, one hope in creating the current stimuli set was to be able to match nouns and verbs on several parameters of item difficulty (e.g., objective visual complexity, word length). However, our group as well as others have found that matching actions and objects on frequency, age of acquisition or picture complexity results in a mismatch on naming difficulty measures. Likewise, matching for difficulty results in a mismatch on other lexical and pictorial properties (Székely et al., 2005). These authors have argued that full orthogonalization of noun and verb names may simply not be possible, at least for the types of verbs that can be represented with our type of line-drawing stimuli.

It has been suggested that some of these effects might be due to the blocking of nouns and verbs (i.e., presenting only nouns or only verbs during one testing session). In fact, most original norming runs (including our own) have been designed in this way. Therefore, in a more recent study we presented participants with a "mixed" design, interspersing noun-verb stimuli within a single PN run (Arévalo, 2002). This study was administered to college-aged students and included counterbalanced easy and difficult items (see below for "difficulty" criteria) as well as contextual cues in the form of aurally-presented lead-in sentences. Contrary to the theory of blocked-design effects, participants in this study named the nouns significantly better (more accurately and faster) than the verbs and benefited from the contextual cue of the congruent (facilitative) sentences, responding faster and more accurately to items which were preceded by congruent lead-ins.

In the current study we extended this mixed-design task to two additional processing conditions (reading and WRP) and four additional participant groups: Broca's, Wernicke's and anomic patients, as well as a group of older control participants.

Difficulty & Ambiguity

As mentioned above, one factor of interest in these studies is naming difficulty. Each item's difficulty score was determined by participants' response times (RT) on previous norming studies using the same stimuli. First, we 'bracketed' the set of possible pictures using response accuracy: here, objects needed to be at least 80% accurate and actions 60% (i.e., the target word was produced by at least 80% and 60% of participants for each object and action word, respectively; the lower number for actions reflects the paucity of actions with high accuracy scores). It is important to note, however, that in our final item selection, the mean accuracy scores for actions and objects did not differ significantly from each other (92.2% for objects and 89.7% for actions) and did not interact significantly with naming performance on the two categories (as assessed by post-hoc analyses). The items were then assigned to difficulty bins, where all items with mean reaction times (RTs) more than 2 standard deviations higher than the grand mean classed as "difficult", and items with RTs more than 2 standard deviations below the mean classed as "easy". Two reaction time numbers were calculated for each item: one for the target name only ("e-rt", or English target name RT) and one for all answers produced to that item ("total-rt"). The difficulty bins were created according to the "total-rt" number, meaning that all answers were considered in determining difficulty level.

One other important factor when working with items which are represented in a 2-D format (especially action concepts) is ambiguity. Naming performance (and relative difficulty) are clearly influenced, among other things, by the level of ambiguity in the representation of a given concept. Other related or contributing variables (already mentioned and accounted for in this data wherever possible) are goodness of depiction, objective and subjective visual complexity, and the fact that actions which take place over time are represented in a static format (this last variable, of course, is a limitation inherent to the nature of the task). Therefore, relative difficulty and ambiguity most likely account for a large portion of the differences in naming performance oberved between actions and objects (or nouns and verbs). However, as mentioned above, much of this ambiguity is inherent to (and therefore more pronounced in) the PN task, for two main reasons: the complexity of pictures relative to written or spoken words, and the fact that all norming measures for this corpus were measured from the original PN studies. Therefore, whereas some variables accounted for (e.g., word length, initial letter frication, meaning behind the word if processed for retrieval) should influence performance mostly in reading and WRP, PN should be more heavily influenced by ambiguity than the other two conditions. This fact should be kept in mind when analyzing groups' performance, as it represents another level at which interesting inter-group differences may be found. For instance, groups may differ in the degree to which difficulty and ambiguity influence their performance, which may be revealing when attempting to interpret each groups' processing abilities, difficulties, and particular strategies.

The Production Mini-Battery

As mentioned above, our main goal with this study was to evaluate participants' production performance on our noun-verb stimuli across the three processing conditions (and two sensory modalities) -- PN, reading and WRP -- within the same testing session. Testing each participant on all three tasks allows for a better comparison of the conditions and modalities to each other as well as across different participants and groups.

Methods

Participants

A total of 41 individuals participated in the current study, with a breakdown as follows: 10 college-aged participants, 10 older control participants (average age 65) and 21 individuals with aphasia. The patient sample contained 10 anomic patients, 6 participants with Broca's aphasia and 5 with Wernicke's aphasia, as classified by the Western Aphasia Battery (Kertesz, 1979; see Appendix A for patient information). 2 additional Wernicke's patients were tested but were not able to complete more than 25% of the task (at least 10 out of 40 items per session), and were therefore excluded from the analyses reported in this work.

All participants had normal (or corrected to normal) vision; as well, they were all tested for hearing with a standard questionnaire and/or with an audiometer. Only patients with a single, identifiable infarct confined to one hemisphere (in this sample, always the left) were included, as well as those patients who were able to complete at least 25% of the task, as mentioned above.

The college-aged participants were recruited from the UCSD campus, and were given course credit for their participation. The older control participants were recruited from the greater San Diego and San Francisco communities, and were paid for their participation. Patients were recruited from the Veterans' Administration (VA) Medical Centers of San Diego and Martinez, CA, and were also paid for their participation.

Stimuli

For this study we used a subset of 120 items from the original action-object PN study mentioned above (Arévalo, 2002) and presented them to each participant in pre-randomized orders across the three conditions. These were 2-D black-and-white line drawings depicting nouns and verbs, acquired from the larger corpus (the CRL-IPNP, Bates et al., 2000). In addition, each target name for the selected pictures was presented as a static word on the computer screen for the reading portion of the experiment. For the WRP condition, the same target words were presented aurally via two small speakers attached to the testing computer. In addition, aurally-presented lead-in sentences preceded each stimulus. All sentences were predictive or facilitative of the lexical category (noun or verb) of the word they preceded and were acquired from Liu (1996). We chose to exclude all neutral lead-in sentences given our confirmation that congruent contexts facilitate naming (Arévalo, 2002), and we wanted to keep such a design when testing patients with known processing difficulties.

Lead-in sentences

For this study we used 7 congruent action sentences and 7 congruent object sentences, listed in Table 1.

Action lead-ins	Object lead-ins
It started to	Here is the
He started to	He wants that
She started to	She wants that
They started to	What about the
I want to	Look at this
They like to	They saw this
When will you	I like this

Procedure

For this experiment, there was 1 across-subjects factor (participant group) and 3 within-subjects factors: condition (PN, reading, WRP), word category (noun vs. verb) and difficulty (easy vs. difficult items). Both accuracy and reaction times (RT) originally served as dependent variables, yet due to the difficulties associated with testing patients with known processing impairments on production tasks, we opted for considering and reporting accuracy scores only (see Scoring below).

Each participant was instructed to sit in front of the computer and attend to the stimuli, which appeared one at a time in separate blocks of 40 items (each block consisted of stimuli from one condition only). Participants first heard a lead-in sentence and were then required to name the picture, read or repeat the word (depending on the block) that was presented to them. They were asked to respond as accurately and quickly as possible into a standing microphone placed in front of them as each stimulus was presented. They were told that some stimuli would represent objects and others actions, and that these would be in random order. They were also asked to provide their best guess when not sure of the answer.

First participants viewed 40 items in one condition, then 40 in another, and the final 40 in the last condition. Next, the lists of 40 would rotate, once for each session (there were 3 sessions per testing run).

This way, across all nine lists, each participant viewed all 120 items three times, with each item appearing once in each of the three conditions. The order in which these sessions were presented was pre-randomized so that not all participants viewed the same order of trials. In addition, for each word category there were 30 "easy" and 30 "difficult" items, as assessed for the original PN study (see Materials & Background above).

The task was presented with the program PsyScope (Cohen et al., 1993) and was experimenter-controlled, meaning that the experimenter manually skipped from trial to trial. Three practice items were incorporated at the beginning of each block in order to acquaint participants with the task and encourage them in case they became frustrated or unmotivated. Participants were allowed breaks between lists if they so wished. If no response was given on a given trial, the microphone would not detect a sound, an "X" would appear on the screen above the trial number and the experimenter could then move on to the next trial.

Scoring

As mentioned above, we began by scoring answers with the scoring system previously established for our norming studies: an answer was counted as correct if it was the appropriate target word and was accurately detected by the microphone. However, as has not been the case in previous studies (or with the control groups in the current study), many answers produced by our patient groups were preceded by non-relevant sounds, caused by circumlocutions, false starts or anomias, leading to a high percentage of non-usable RTs (in some cases as high as 15% of good answers given). Therefore, we decided to exclude the RT measure and focus on accuracy for all "usable" (i.e., intelligible) responses. We consider this method to be more complete and informative, as well as less confounding.

For patients, special attention was given to individual answers to allow for future error analyses. In addition, some phonological variations of the target answer were considered correct (given they were similar enough to the target concept). Namely, if at most two incorrect phonemes were produced but the answer was understandable independently of the context (the scorer did not look at the correct answers when scoring responses), the answer was considered correct (as described in Martin et al., 1994). Steering away from the standard scoring method also allowed us to consider alternative answers produced by our participants, thus creating a more accurate view of performance abilities and difficulties.

Results

Groups differed greatly from each other on overall task performance: across the three conditions, the highest accuracy was seen for the control groups (with the college group performing slightly better than the older control participants), followed by the Anomics, then Broca's and finally Wernicke's patients ($F(1,4) = 516.8056$, $p<.0000$). In addition, there was a main effect of Condition: as mentioned above, we expected to see lower performance on PN, due to higher difficulty and ambiguity levels inherent to the PN task relative to the other two conditions. This was true for our college-aged participants, for which the items were originally normed. But in addition, relative to the college group, all other groups were less accurate at PN relative to the other two tasks. In the case of both control groups and Anomic patients, WRP and reading were virtually the same; for severe patients, on the other hand, WRP was more accurate than reading. A main effect of word Category was also significant overall ($F(1,1) = 26.7899$, $p<.0001$), with participants responding significantly more accurately to nouns than to verbs. Finally, there was a main effect of Difficulty ($F(1,1) = 199.1002$, $p<.0001$), with easy items yielding comparatively more accurate scores.

Several 2-way and 3-way interactions were also significant, and these are listed in Table 2 below.

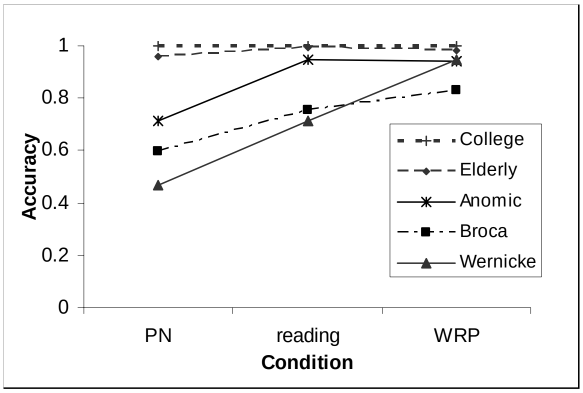
<u>Table 2</u>: Significant Interactions (Accuracy)

Interaction	F-value	p-value
G x C	F(1,8) = 40.9641	P<.0001
G x D	F(1,4) = 10.0556	P<.0030
G x W	F(1,4) = 2.4147	P<.0466
C x D	F(1,2) = 104.5010	P<.0001
C x W	F(1,2) = 53.6039	P<.0001
G x C x D	F(1,8) = 4.3473	P<.0001
G x C x W	F(1,8) = 2.7795	P<.0045
C x W x D	F(1,2) = 4.0637	P<.0172

G = group, C = condition, D = difficulty, W = word category

PN was the most challenging task for control and patient groups alike, and patients revealed comparatively greater difficulty on it (relative to control groups as well as to their own performance on the other two tasks). In other words, this condition seemed to be particularly challenging for patients. Perhaps patients have a lower threshold, or breaking point, and are therefore more susceptible to factors which are inherently more pronounced in PN, such as overall ambiguity. This result is illustrated in Figure 1.

Fig. 1: Group x Condition



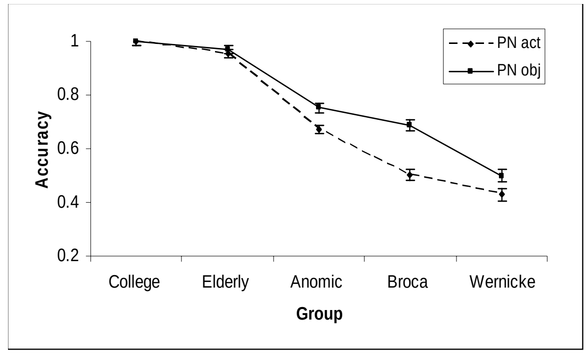
All groups were significantly less accurate in PN relative to the expected lowered performance for college participants. Also, patients showed a greater discrepancy in performance between PN and the other two conditions, w/ worse performance on reading than on WRP for the severe groups (significantly more pronounced for Wernicke's patients).

In addition, difficulty affected groups and conditions differently. For the reading and WRP tasks, only the severe aphasic patients were significantly less accurate at producing the difficult items, whereas control participants and Anomic patients performed equally well on both easy and difficult items (suggesting that difficulty level was irrelevant for these groups in the "easier" conditions).

Finally, poorer performance on verb processing was only significant in the PN condition, and not in the other two tasks. In other words, verb pictures were less accurately named than noun pictures, but verb words and sounds did not differ significantly from written and spoken nouns. Figures 2 through 4 below illustrate how this noun-verb dissociation manifested itself across groups and conditions.

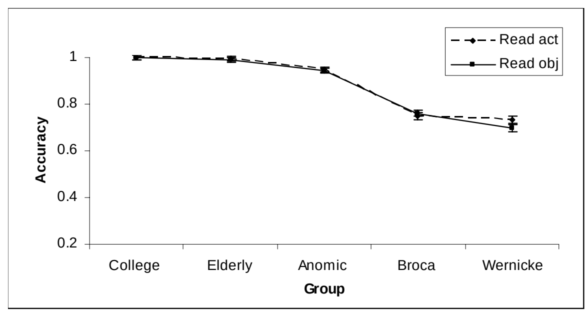
Finally, a set of post-hoc analyses were conducted to see whether other relevant variables influenced participants' performance on the three tasks. These were number of syllables and number of letters (relevant to reading and WRP), initial letter frication, word frequency, AoA (age of acquisition), and visual complexity (relevant mostly to PN). No significant effects on performance were found.

Fig. 2: PN: Group x Word Category



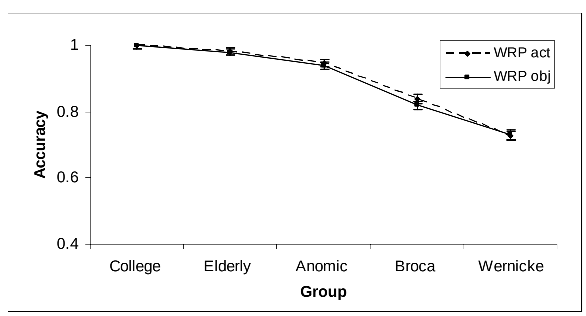
In PN, all participants were sig. less accurate at processing actions than objects, with patient groups displaying greater discrepancy between the categories. F(1,4) = 4.1614, p<.0023

Fig. 3: Reading: Group x Word Category



The noun-verb difference did not manifest itself in the Reading condition. The apparent difference for Wernicke's patients did not reach significance. Group x Word Category: F(1,4) = 0.8538, p<.491

Fig. 4: WRP: Group x Category



As in Reading, no significant noun-verb differences were observed in WRP. Group x Word Category: F(1,4) = 0.2368, p<.9177

Summary

With this study, we set out to investigate action-object (noun-verb) dissociations across different tasks, sensory modalities and participant groups. We wanted to compare group performance across conditions and test the noun-verb double-dissociation previously reported for aphasic patients. Therefore, we tested a group of Anomics, Broca's and Wernicke's patients (as well as college-aged and older control groups) on a task which included a set of noun and verb stimuli presented in a counterbalanced design across three tasks previously used in patient testing: Picture-naming (PN), word reading and word repetition paradigm (WRP).

Our results were as follows: first, as expected, PN was significantly more difficult for all participants tested. It is by nature a more complex task, thus requiring a greater number of processing steps (see Picture-naming (PN), reading & word repetition paradigm (WRP) above). In addition, it was the original task on which many variables known to influence processing were normed, and as such contains greater discrepancy between action and object pictures on factors such as naming difficulty and ambiguity (most likely also present, yet to a lesser degree, in reading and WRP). Therefore, all participants were significantly less accurate at PN than at reading and WRP. In addition, relative to college control performance, all other groups (and in particular the aphasic groups) revealed a greater discrepancy in performance between PN and the other two tasks. In other words, aphasic performance dropped significantly on the more challenging task relative to the other two (more so than for the control groups). Perhaps this suggests that when processing abilities are compromised (as in the case of patients and to a lesser degree, aging healthy people), complicating factors, such as naming difficulty and ambiguity in the representation of an item, may inflict a stronger weight on participants' performance. In other words, individuals with compromised abilities may have fewer strategies to rely on as well as a lower threshold or breaking point, reflected in their performance on the "less straightforward" tasks, such as PN. A similar "lower threshold" profile was seen for Anomics on difficulty, another factor of interest included in our design. Whereas their performance on "easy" items (in PN) was almost in the healthy control range (79% accuracy), their performance on "difficult" items dropped significantly (to 51% accuracy, within the severe patient range). Performance on reading and WRP did not differ significantly from each other for the control groups and the Anomic patients (the least compromised of the patient groups). For the more severe groups, however (Broca's and Wernicke's patients), WRP was significantly more accurate than reading.

In addition, PN was the only condition in which performance on nouns vs. verbs differed significantly, suggesting that word class dissociations may be specific to word-retrieval processes (at least for this type of mixed design). Furthermore, the type of dissociation seen was consistent across control and patient groups alike: verbs were always named less accurately. As mentioned above, relative average difficulty values for the two categories cannot be held solely responsible for the difference in performance on this particular set of stimuli and participants. Most likely it is a combination of factors that leads to such dissociations, such as inherent ambiguity in the representation of actions and objects using 2-D picture stimuli (leading to greater variability in the possible names given for a given verb item relative to a given noun item, particularly in the PN task), as well as inherent differences in the relative complexity of conceptualizing action vs. object concepts (the effects of which are most evident in a task requiring greater processing steps, such as PN). In this study we considered a number of alternative answers (both for nouns and verbs) as equally correct, thus reducing the limitations of a strict coding method in which various "equally acceptable" alternative answers go unnoticed. However, we could not completely account for a probable higher ambiguity in actions, which most likely influence, to some degree, groups' naming performance on actions vs. objects and on PN vs. the other two processing conditions.

Conclusions

As mentioned above, the stimulus set used in this study was counterbalanced for word category and difficulty. The original categories of interest represented a morphosyntactic distinction: the lexical classes of noun vs. verb. No clearly defined semantic divisions were intentionally incorporated into the design. In addition, we controlled for a number of different variables known to influence word and picture processing.

If aphasic patients' performance on this task had been equally poor across conditions and word categories, little could be deduced about what exactly is impaired in processing after brain injury. However, for this group of participants, aphasic patients largely mimic the control profile, but at a lower performance level. In other words, they perform significantly worse than the controls, yet their performance pattern is no different: verbs are processed with greater difficulty than nouns regardless of aphasia classification. This is especially true on the PN task, which most likely requires the most amount of semantic processing. Therefore, unlike a scenario in which participants perform at ceiling levels or below 25% accuracy, the profile seen for these patients is highly informative.

As more patients are tested on this task and neuroimaging techniques are applied, we hope to gain a more precise map of specific processing areas or networks involved in the tasks of interest. The present data suggest that the way in which language may break down in aphasia (and the way in which healthy brain systems are organized) may not depend on the morphosyntactic noun-verb distinction held accountable in classic theories of language processing in aphasia. Rather, deeper, semantically-based features associated with the particular stimuli chosen may be responsible for significant dissociations in performance. Our next step was to investigate these possible dissociations.

Of course, imaging the healthy brain is not a direct route to understanding performance after brain damage has taken place. Depending on the nature of the damage incurred, patients are more or less able to compensate for their level of impairment. Therefore, we plan to complement traditional imaging methods normally used on healthy control participants (i.e., fMRI) with recent tools which can be invaluable when the focus of interest is a set of patients with brain damage (VLSM, Bates et al., 2003). We are certain that further testing with additional participants and methods will add valuable information to our body of knowledge and bring us one step closer to understanding how meaning is organized in the brain, both before and after brain injury. The present data represent an important step in this process.

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Appendix A

Participant Information is listed below by: initials, age, site of testing (S = San Diego, CA; M = Martinez, CA), and aphasia classification.

Initials	Age	Site	Aphasia Type
JC	81	S	Anomic
CH	67	S	Anomic
PB	77	S	Anomic
KW	66	S	Anomic
LR	57	S	Anomic
BK	57	M	Anomic
JW	75	S	Anomic
JH	64	S	Anomic
SA	77	M	Anomic
DH	56	M	Anomic
MB	51	S	Broca
WR	59	M	Broca
DC	65	S	Broca
DF	48	M	Broca
EB	33	M	Broca
MC	55	M	Broca
VH	73	S	Wernicke
WT	67	M	Wernicke
FY	79	M	Wernicke
RS	76	M	Wernicke
PP	51	S	Wernicke

Appendix B

Object pictures: RT-total refers to mean reaction times for previous studies conducted at CRL; RT-target refers to reaction times for dominant responses only; Ln frequency is the log natural frequency for each word's dominant response; VisComplexity is each picture's objective visual complexity based on its picture file size in jpg format.

No.	Picture Name	RT-total	RT-target	Ln freq	Visual Complexity
1	Accordion	1216	1179	0.69	21540
2	Airplane	800	778	1.95	16810
3	Ax	1119	1085	2.3	7849
4	Baby	751	729	5.56	18598
5	Balloon	702	702	1.95	8015
6	Bed	706	706	5.14	13761
7	Bell	703	703	3.33	11109
8	Bicycle	751	731	1.79	24322
9	Bread	774	773	4.32	10161
10	Cannon	1159	1159	1.95	17678
11	Carrot	806	806	2.2	13201
12	Chimney	1169	1169	2.4	9730
13	Clock	776	772	3.69	25639
14	Comb	717	717	1.79	28324
15	Cow	1115	1079	3.71	17300
16	Door	719	719	5.96	12638
17	Drum	779	766	2.83	39085
18	Faucet	1168	1130	1.1	17509
19	Fishingrod	1231	1213	0	5685
20	Fork	723	723	2.77	8818
21	Glasses	766	758	3.5	11525
22	Handcuffs	1139	1113	1.1	21347
23	Hat	692	684	4.23	8732
24	Ironingboard	1110	1105	0	12848
25	Kite	796	796	1.79	17880
26	Lizard	1229	1155	1.61	12070
27	Moon	804	804	4.09	3730
28	Onion	1115	1100	2.83	11645
29	Orange	1129	1098	3.04	10314
30	Package	1088	1102	3.04	29767

No.	Picture Name	RT-total	RT-target	Ln freq	Visual Complexity
31	Pants	779	757	2.83	16138
32	Purse	780	772	2.4	21948
33	Rabbit	742	746	3	11295
34	Ring	785	785	1.39	7652
35	Sandwich	775	775	0	13607
36	Saxophone	1103	1061	0.69	8795
37	Screwdriver	1179	1179	1.39	9051
38	Seahorse	1157	1132	0	9744
39	Seal	1221	1115	2.71	12172
40	Shell	1129	1101	3.85	18590
41	Skeleton	817	817	2.56	10724
42	Sled	1198	1188	0.69	16722
43	Smoke	1212	1221	3.89	10642
44	Snake	775	775	3.18	23761
45	Sock	712	712	2.94	8316
46	Squirrel	1225	1234	1.95	21975
47	Submarine	1144	1145	2.89	12481
48	Tank	1181	1155	3.69	11180
49	Telephone	761	752	4.66	19758
50	Television	799	786	0	18950
51	Tent	744	744	3.81	16963
52	Turkey	1159	1160	1.79	15338
53	Turtle	734	734	1.61	14768
54	Umbrella	738	738	2.71	15140
55	Unicycle	1173	1179	0	20238
56	Vase	1168	1171	2.08	20221
57	Waiter	1161	1156	3.14	27418
58	Wheelbarrow	1226	1207	0.69	20045
59	Worm	1106	1110	2.89	20764
60	Yoyo	1155	1141	0	8066

Appendix C

Action pictures: RT-total refers to mean reaction times for previous studies conducted at CRL; RT-target refers to reaction times for dominant responses only; Ln freq is the log natural frequency for each word's dominant response; Visual Complexity is each picture's objective visual complexity based on its picture file size in jpg format.

No.	Picture Name	RT-total	RT-target	Ln freq	Visual Complexity
1	Bark	949	949	2.4	18031
2	Beg	1348	1292	3.43	17686
3	Blow	1534	974	4.44	19790
4	Box	967	963	0.69	16757
5	Brush	903	888	3.22	23911
6	Carry	1253	1180	5.74	17053
7	Climb	1001	989	4.53	37429
8	Cough	1334	1255	2.56	33349
9	Cry	962	934	4.8	22897
10	Curl	1346	1326	2.77	27471
11	Curtsey	1306	1203	0.69	14133
12	Cut	1065	1065	5.25	18411
13	Dance	993	979	4.2	30516
14	Dip	1317	1294	2.89	20402
15	Drip	980	947	2.4	15971
16	Drive	999	989	5.39	35400
17	Dust	1215	1209	2.2	13403
18	Erase	1319	1244	1.61	23620
19	Fall	1134	1159	5.69	26229
20	Feed	1241	1208	4.9	22683
21	Fly	914	914	4.57	13178
22	Follow	1318	1321	5.69	19976
23	Frighten	1322	1246	2.08	24409
24	Give	1330	1343	7.15	27760
25	Greet	1216	1174	4.88	34427
26	Hunt	1254	1282	3.4	45398
27	Iron	977	977	1.79	13323
28	Kick	866	853	3.76	17222
29	Kneel	1331	1252	3.18	14002
30	Lick	1120	1100	2.48	18076
31	Light	1298	1304	4.01	20907
32	Listen	1245	1263	5.18	37439
33	Mail	1246	1134	1.61	25541
34	Mop	1332	1258	1.95	20337
35	Point	1102	1063	4.89	16800
36	Pop	1261	1121	3	15804
37	Pour	890	852	4.38	26916
38	Pray	1224	1216	3.37	45299
39	Pull	1255	1223	5.23	30784
40	Reach	1300	1261	5.55	18105
41	Read	993	993	5.92	30065
42	Run	912	918	6.09	17276
43	Salute	1028	1028	1.39	15575
44	Shoot	1032	1012	4.32	19808
45	Shower	974	947	1.95	28383
46	Ski	1428	1053	1.95	17193
47	Slide	913	886	3.58	32449
48	Slip	1238	1231	4.13	27692
49	Smile	1119	1107	5.09	40153
50	Snow	1266	1221	1.61	44104
51	Spread	1351	1367	4.49	25846
52	Squeeze	1133	1128	3.37	17216
53	Sweat	1239	1201	2.89	16947
54	Swim	852	852	3.87	16766
55	Swing	874	874	4.04	18530
56	Tickle	1258	1172	1.61	18027
57	Tie	1093	1099	4.13	23682
58	Vacuum	996	993	0.69	30285
59	Wave	1224	1207	3.83	15853
60	Yell	1266	1249	3.14	20192