APHASIOLOGY, 1998, VOL. 12, NO. 7/8, 745–753

# Linguistic contextual influences on categorization skills after traumatic brain injury

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## Abstract

This study examined the effect of linguistic context on the graded structure representation of common categories in adults with traumatic brain injury (TBI). Graded structure indicates that all members of a category are not equally representative with some members being better examples than others. Ten adults who had suffered traumatic brain injuries as the result of motor vehicle accidents and 10 age- and gender-matched neurologically intact adults participated in the study. The experimental task consisted of presenting each participant with 20 contextual sentences and asking them to select the best example of a category label mentioned in each sentence. Each of the 20 sentences were followed by six exemplars: four exemplars of the common category label mentioned in the sentence and two exemplars that were members of other categories. The specific exemplar of the category label was inferred by the context meaning. The neurologically intact adults were significantly more accurate than the TBI adults in choosing the best category example. However, error patterns were similar for each group with both groups choosing a significantly higher proportion of true unrelated exemplars than any other type of error. Results are discussed relative to the process of restructuring common category graded structure as a result of semantic constraints imposed by linguistic context and limitations in cognitive flexibility observed in TBI adults.

## Introduction

A category represents a group of distinguishable objects, events, or items which are considered to be equivalent (Mervis and Rosch 1981, Rosch and Mervis 1975). Categorization is the process by which persons group together different but equivalent stimuli into the same class by deciding whether a specific item belongs to a particular class. This process plays a primary role in concept formation. A concept is all the knowledge an individual has relative to a class of objects or events (Anglin 1977, Keil 1989, Medin and Smith 1984, Smith and Medin 1981). Categorization research has been a major means of evaluating non-brain-damaged and brain-damaged adults' knowledge of concepts.

Categorization abilities have been found to vary as a function of category type. One type of category, common categories, are natural object concepts (e.g. 'birds')

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that have graded structure (Rosch 1975, Rosch and Mervis 1975). Graded structure indicates that all members of a category are not equally representative with some members being better examples than others. Better examples have been identified as more typical members. Common categories are conceived relative to the ideal representative category example. An example's similarity to this ideal or prototype determines its typicality.

Several researchers have investigated the influence of linguistic context on the graded or typicality structure distribution of common categories within normal adults (Barsalou 1987, Roth and Shoben 1983, Whitney and Kellas 1984, Whitney 1986). Roth and Shoben (1983) examined the relationship between typicality structure of common categories generated when category labels are presented in isolation and the typicality distribution of category examples generated when category labels are presented in semantically constrained linguistic contexts. For example, in the sentence 'The *bird* walked across the barnyard', 'chicken' is a better representative example of 'bird' than 'robin'. However, in the absence of this sentence context, 'robin' is judged to be a more typical 'bird'. Roth and Shoben found that common category labels presented in the sentence contexts generated different graded structure distributions for category members from distributions generated for category labels in the absence of explicit context. Barsalou (1987, 1992, 1995) and others (Whitney 1986) have purported that context changes the relationship between category labels and examples during comprehension; consequently, the entire graded structure distribution is restructured as a result of constraints imposed by context. Barsalou (1992, 1995) has suggested that this restructuring process requires cognitive flexibility in an individual's inferential thinking abilities.

Research with traumatically brain injured (TBI) adults has revealed that higher functioning TBI individuals are aware of graded structure for common categories (Lohman *et al.* 1989). However, Hux *et al.* (1993) observed that TBI adults performed in a significantly different manner from normal adults in ranking common category member typicality. These authors suggested that this could be due to ineffective searching strategies and difficulty in inferential analysis. Thus, as a result of these findings, one may guess that TBI adults would experience some difficulty in restructuring category graded structure when presented with semantically constraining linguistic contexts. Current research minimally addresses whether TBI adults are able to utilize contextual information to facilitate processing of semantic knowledge. Therefore, the present investigation examined the effect of context on the graded structure distribution of common categories for adults with traumatic brain injury.

## Method

### *Subjects*

Twenty adults, consisting of 10 TBI individuals and 10 neurologically intact age- and gender-matched controls, participated in the study. Subject characteristics are presented in table 1. TBI subjects were functioning at levels 5–8 on the Ranchos Los Amigos Levels of Cognitive Functioning Scale (Hagen and Malkmus 1979, Malkmus *et al.* 1980). Education was noted but subjects were not matched on this variable because many TBI adults were in the midst of their education when their injury occurred. All head injuries were the result of a motor vehicle accident. Brain

**Table 1. Subject characteristics**

| Subject | Age | Gender | Years of education | Months post-injury | Ranchos level |
|---|---|---|---|---|---|
| TBI | | | | | |
| 1 | 24 | M | 14 | 5 | 7 |
| 2 | 47 | M | 12 | 3 | 6 |
| 3 | 53 | M | 12 | 13 | 8 |
| 4 | 38 | M | 12 | 16 | 7 |
| 5 | 20 | F | 13 | 4 | 8 |
| 6 | 17 | M | 11 | 22 | 8 |
| 7 | 21 | F | 15 | 6 | 5 |
| 8 | 20 | M | 14 | 2 | 5 |
| 9 | 20 | M | 14 | 5 | 6 |
| 10 | 37 | M | 12 | 32 | 8 |
| Range | 17–53 | | 12–15 | 2–32 | |
| Mean | 29·7 | | 13·4 | 10·8 | |
| SD | 13·0 | | 1·4 | 9·4 | |
| NBD | | | | | |
| 1 | 24 | M | 16 | | |
| 2 | 49 | M | 12 | | |
| 3 | 59 | M | 14 | | |
| 4 | 32 | M | 10 | | |
| 5 | 21 | F | 12 | | |
| 6 | 19 | M | 13 | | |
| 7 | 24 | F | 16 | | |
| 8 | 25 | M | 13 | | |
| 9 | 25 | M | 13 | | |
| 10 | 34 | M | 14 | | |
| Range | 19–59 | | 10–16 | | |
| Mean | 31·2 | | 13·3 | | |
| SD | 12·4 | | 1·7 | | |

TBI, traumatic brain injured; NBD, non-brain-damaged.

damage was verified by neurological examination and clinical reports. All participants had no history of pre-morbid learning disabilities or special education placement, previous neurologic insult, or psychiatric disturbance. All subjects were right-handed and native speakers of English.

Pre-experimental clinical test data for all subjects are presented in table 2. All subjects were administered the *Test of Adolescent/Adult Word Finding* (TAWF) (German 1990) and the *Boston Naming Test* (BNT) (Kaplan *et al.* 1983) to examine word retrieval and naming skills. All subjects also were administered the *Peabody Picture Vocabulary Test—Revised* (PPVT-R) (Dunn and Dunn 1981) to assess receptive vocabulary. All TBI subjects were administered the Cognitive Language Assessment (CLA) (Pierce *et al.* 1990) to determine the extent of cognitive/linguistic involvement. This test was developed specifically for use with patients who exhibit moderate and high levels of cognitive functioning based on the Ranchos Los Amigos Scale (Hagen and Malkmus 1979, Malkmus *et al.* 1980). The test examines the areas of organization, recall, and higher level thought processes, utilizing principles of assessment of the TBI population established by Adamovich *et al.* (1985, Adamovich 1990). All subjects passed a pure-tone bilateral hearing screening. Subjects were required to achieve at least 70% accuracy on auditory

**Table 2. Clinical test data**

| Subject | PPVT-R[a] | TAWF[a] | BNT[b] | CLA[b] |
|---|---|---|---|---|
| TBI | | | | |
| 1 | 84 | 94 | 50 | 53 |
| 2 | 62 | < 59 | 31 | – |
| 3 | 93 | 70 | 39 | 51·5 |
| 4 | 71 | 67 | 47 | 36 |
| 5 | 78 | 65 | 38 | 58·5 |
| 6 | 80 | 94 | 48 | 40 |
| 7 | 55 | < 52 | 28 | 29 |
| 8 | 88 | 72 | 43 | 49 |
| 9 | 89 | 68 | 46 | 46 |
| 10 | 79 | 82 | 47 | 30 |
| Range | 55–93 | < 52–94 | 31–50 | 29–58·5 |
| Mean | 77·9 | 72·3 | 41·7 | 39·6 |
| SD | 12·1 | 13·2 | 7·1 | 10·5 |
| NBD | | | | |
| 1 | 110 | 102 | 55 | |
| 2 | 99 | 101 | 53 | |
| 3 | 106 | 123 | 57 | |
| 4 | 79 | 102 | 52 | |
| 5 | 82 | 82 | 45 | |
| 6 | 95 | 91 | 42 | |
| 7 | 94 | 111 | 55 | |
| 8 | 104 | 129 | 58 | |
| 9 | 100 | 102 | 58 | |
| 10 | 100 | 111 | 60 | |
| Range | 79–110 | 82–129 | 42–60 | |
| Mean | 96·9 | 105·4 | 53·5 | |
| SD | 9·4 | 13·2 | 5·5 | |

[a] Standard scores.
[b] Raw scores.
TBI, traumatic brain injured; NBD, non-brain-damaged. PPVT-R, *Peabody Picture Vocabulary Test—Revised*; TAWF, *Test of Adolescent/Adult Word Finding*; BNT, *Boston Naming Test*, maximum score = 60; CLA, Cognitive Language Assessment, maximum score = 82.

in the study. The categorization screening test required the individual to choose the best example of each common category label utilized in the experimental task when the category label was presented in isolation.

### *Materials*

The experimental task consisted of 20 sentences. A stimulus example is presented in table 3. Each sentence was followed by six exemplars: four exemplars of a common category label mentioned in the sentence and two out-of-category exemplars that were members of other categories. The sentences were contextual in that the specific exemplar of the category label was inferred by the context meaning. The four within-category exemplars differed in relatedness to the category label; two exemplars were possible referents (true items) and two were not referents (false items). The false items were referents of the category term in

**Table 3. Stimulus item example**

| | |
|---|---|
| Context sentence: Mike told Denise that she could find a pen in the centre drawer of the piece of 'furniture' | |
| Within-category items | |
| False items | |
| Related exemplar | Chair |
| Unrelated exemplar | Mirror |
| True items | |
| Related exemplar | Desk |
| Unrelated exemplar | Dresser |
| Out-of-category items | |
| Related exemplar | Refrigerator |
| Unrelated exemplar | Dog |

isolation. However, in the context sentence, the false items either violated explicitly mentioned constraints or violated constraints that could be validly inferred from the context sentence. For both true and false items, one item (related exemplar) was more related to the category representation in context than the other (unrelated exemplar). Out-of-category items consisted of one related and one unrelated item. Context sentences, within-category items, and relatedness ratings were based on norms established by Roth and Shoben (1983). Out-of-category items and task format were taken from Jordan (1990).

### *Procedure*

Stimuli were presented simultaneously through live voice and displayed graphically. The category label was visually highlighted within the context sentence and was emphasized by saying 'The category label is ____' after presentation of each stimulus item. Subjects were asked to indicate the best exemplar for the category label in the sentence by pointing to the visually presented item or providing the response verbally. Subjects were presented with two practice items. For the experimental task, 2 minutes were provided to respond to each of the 20 stimulus items. For items answered incorrectly, a comprehension assessment was administered which consisted of placing each within-category example from each of the stimulus items on the experimental task in a sentence completion format. Each sentence was followed by four foils. One of the foils represented the category label of the particular category example. The assessment was administered to ensure that incorrect responses were the result of cognitive/linguistic limitations rather than unfamiliarity with exemplars.

## Results

The number of accurate responses on the exemplar identification task was determined for each group. table 4 is a display of the mean proportion of accurate responses for the two groups. An independent $t$-test conducted on these data revealed that the non-brain-damaged subjects were significantly more accurate than the TBI group in choosing the best category example for the contextual sentences ($t = 3{\cdot}98$; $p < 0{\cdot}0009$).

**Table 4. Mean proportion of accuracy on the exemplar identification task for the TBI and non-brain-damaged adults**

| | Mean | Standard deviation | Range |
|---|---|---|---|
| TBI | 0·760 | 0·139 | 0·500–0·900 |
| NBD | 0·925 | 0·042 | 0·850–1·0 |

TBI, traumatic brain injured; NBD, non-brain-damaged.

**Table 5. Mean proportion of errors for each error type based on the total number of errors**

| | FR | OR | TU | FU | OU |
|---|---|---|---|---|---|
| TBI | 0·228[a] | 0·058 | 0·623 | 0·092 | 0·000 |
| | (0·197)[b] | (0·097) | (0·322) | (0·173) | (0·000) |
| NBD | 0·216 | 0·000 | 0·683 | 0·000 | 0·000 |
| | (0·284) | (0·000) | (0·364) | (0·000) | (0·000) |

[a] Proportions represent the number of errors for each error type based on the total number of errors.
[b] Standard deviations are in parentheses.
TBI, traumatic brain injured; NBD, non-brain-damaged; FR, false-related; OR, out-of-category related; TU, true-unrelated; FU, false-unrelated; OU, out-of-category unrelated.

The number of errors for each error type based on the total number of errors was determined for the two groups. The pattern of errors was determined by examining the incorrect foils chosen for each stimulus. As mentioned previously, the other foils aside from the correct response were: false related, out-of-category related, true unrelated, false unrelated, and out-of-category unrelated. A display of the mean proportion of errors per error type based on the total number of errors for each group is presented in table 5. Two-sample independent $t$-tests ($\alpha = 0{\cdot}01$) were conducted between groups for each error type, yielding no significant differences between groups for any error type. Multiple Sidak $t$-tests were conducted within groups between each error type ($\alpha = 0{\cdot}01$). Results revealed that both groups identified a significantly higher proportion of true unrelated items than any other error type ($t = 2{\cdot}61$; $p < 0{\cdot}008$) and significantly more false related items than all error types except true unrelated ($t = 2{\cdot}22$; $p < 0{\cdot}01$). Thus, the error patterns were similar for each group. In regard to the comprehension assessment, the TBI subjects consistently had knowledge of the foils for the incorrect stimulus items.

## Discussion

The TBI adults were less sensitive to the contextually constrained categories than the non-brain-damaged individuals as they did not consistently identify the best example inferred by the category term in the contextual sentence. As suggested previously, the ability to restructure a category's typicality distribution requires cognitive flexibility (Barsalou 1992, 1995). If correct, appropriate apprehension of the contextual information requires the individual to revise their initial interpretation based on the current linguistic condition. TBI adults have been found to display reduced flexibility in reasoning and problem-solving, particularly having difficulty in their analyses of inferential problems (Adamovich 1990, Gillis 1996, Hartley 1995, Sohlberg and Mateer 1989, Stuss 1987, van Zomeren and Brouwer 1994). These impairments have been identified as components of the executive control deficit often observed in TBI adults exhibiting varying degrees of severity of cognitive deficit. In this particular task, executive control dysfunction may restrict utilization of linguistic context, thus resulting in subtle problems in interpreting semantic information.

The TBI adults committed a small proportion of out-of-category errors, all being related in nature. This finding is consistent with observations of Lohman *et al.* (1989). Although their TBI subjects retrieved fewer common category examples than non-brain-damaged adults on exemplar generation, their within-category responses in regard to which category members constituted good examples were relatively intact. In the present investigation, a large majority of the errors chosen by the TBI participants were within-category true responses, even though they frequently were unrelated items to the category label in the contextual sentence. This pattern was similar to that displayed by the normal adults. Therefore, the TBI individuals may have utilized context to some degree to determine category representativeness. However, the linguistic processing requirements of the task in conjunction with limitations in cognitive flexibility of the TBI adults may have impeded the accuracy of these individuals. As mentioned, the graded structure continuum appears to change with the presence of specific context. This restructuring appears to occur because different category concepts are used in different contexts for the same category. Reduced cognitive flexibility of the TBI adults may result in utilizing some features of the same concept and some features of a different concept in different linguistic contexts to interpret the sentential information. Consequently, the resulting interpretation may be a response choice that is true, in the sense that it is plausible in the particular context (i.e. it contains some features), but unrelated to the particular situation referred to in the contextual sentence.

An alternative explanation for the current findings may be that the TBI adults display subtle but persisting problems in organizational skills. Categorization is a major component of the organization process, reflecting one's ability to organize one's environment (Barsalou 1987, 1992, Rosch and Mervis 1975). The act of categorization involves associating information with linguistic symbols and classifying stimuli according to their salient features (Rosch 1978). In the present study, the TBI adults were successful at identifying the best category example for the common category labels when the labels were presented in isolation on the pre-experimental categorization screening. Introduction of the sentential contexts increases the complexity of the task, however, and may adversely affect the use of internal organizational strategies, such as categorization, for the TBI individuals. It is also possible that presentation of the sentence contexts degrade, rather than restructure, graded structure distributions for category representations in memory for TBI adults. Consequently, the TBI adults may have had difficulty with the categorization process because they could no longer identify the most salient features of the stimulus items (Kennedy and DeRuyter 1991).

As indicated, several explanations have been provided regarding the underlying basis of the residual word-finding problems exhibited by the TBI individuals in the current investigation. Distinction between these explanations may be important because the focus of therapeutic intervention for these problems often depends upon the underlying basis of the deficit. Furthermore, the basis of the word-finding deficit may change as the individual's level of cognitive functioning changes. Specifically, word-finding impairments are not usually apparent in TBI patients until they are at least functioning at level IV on the Ranchos Los Amigos Scale. Prior to this level of cognitive functioning, patients usually are not able to discriminate, sequence, or organize information adequately (Hagen and Malkmus 1979, Malkmus *et al.* 1980). In TBI individuals functioning at levels IV and V, treatment of word-finding problems should focus on the cognitive process of organization. Particular emphasis should be placed on categorization and association, with tasks involving identification, matching, sorting, and classifying objects/pictures. With these individuals, minimal attention should be devoted to treatment of word finding as it relates to language (Gruen *et al.* 1990).

In TBI patients functioning at levels VI, VII, and VIII of the Ranchos Los Amigos Scale, treatment of word finding should include intervention on memory functioning as well as language functioning (Gruen *et al.* 1990, Kennedy and DeRuyter 1991). This group includes the majority of TBI patients in the current investigation. Memory tasks should involve recall activities and inplementation of general retrieval strategies. Language tasks should facilitate impaired lexical retrieval, such as pre-stimulation cueing, various cueing hierarchies, and increased lexical focus, as well as developing compensatory strategies for coping with their residual deficits (Giles and Clark-Wilson 1993, Linebaugh 1997).

Caution should be taken when interpreting these findings in light of the limited number of subjects and the varied cognitive levels of the TBI adults within this sample. Time post-injury may need to be explored relative to severity of cognitive involvement when assessing TBI patients' ability to utilize linguistic context to infer sentence meaning. Further research also should consider the nature of the task, particularly regarding task complexity and on-line activation of exemplars of common categories when examining TBI adults' processing of categorical concepts in context.

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