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Effect of typicality on online category verification of animate category exemplars in aphasia

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Abstract

Normal young, elderly, Broca's aphasic, and Wernicke's aphasic individuals participated in an online category verification task where primes were superordinate category labels while targets were either typical or atypical examples of animate categories or nonmembers belonging to inanimate categories. The reaction time to judge whether the target belonged to the preceding category label was measured. Results indicated that all four groups made significantly greater errors on atypical examples compared to typical examples. Young and elderly individuals, and Broca's aphasic patients performed similarly on the verification task; these groups demonstrated faster reaction times on typical examples than atypical examples. Wernicke's aphasic patients made the most errors on the task and were slowest to respond than any other participant group. Also, these participants were not significantly faster at accepting correct typical examples compared to correct atypical examples. The results from the four groups are discussed with relevance to prototype/family resemblance models of typicality.
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Keywords: Typicality; Aphasia; Reaction times; Category prototype

1. Introduction

Much research in psychology has been focused on the representation of semantic categories. The classical view of categories being represented by a set of defining features that allows equivalent probability of membership for all members (Bruner, Goodnow, & Austin, 1956) has been replaced by the observation that not all members of a category are equal (Posner & Keele, 1968; Rosch, 1973, 1975). It has been found that some items are judged as good or typical members (e.g., *robin*) of a category (e.g., *bird*) while others are judged poor or atypical members (e.g., *ostrich*, Rosch, 1975). It has also been found in several studies that typical examples receive preferential processing relative to other examples in the category and this phenomenon has been labeled the typicality effect (Hampton, 1979; McCloskey & Glucksburg, 1978; Posner & Keele, 1968; Rips, Shoben, & Smith, 1973; Rosch, 1973, 1975).

The typicality effect has been shown using various experimental paradigms including: (a) subjects' ratings of typicality of items within a category (Rosch, 1975; Uyeda & Mandler, 1980), (b) the order in which category items are learned (Posner & Keele, 1968; Rosch, 1973; Rosch & Mervis, 1975), (c) probability of item output within a category (Mervis, Catlin, & Rosch, 1976; Rosch, 1975; Uyeda & Mandler, 1980), (d) expectations generated by category names (Rosch, 1975), and (e) category naming frequency (Casey, 1992; Hampton, 1995). More relevant to the present experiment, typicality has also been found to predict verification time for category membership (Hampton, 1979; McCloskey & Glucksburg, 1978; Larochelle & Pineu, 1994; Rips et al., 1973; Smith, Shoben, & Rips, 1974). All these studies have found faster reaction times for typical examples than for atypical examples during a category verification task. The typicality effect is also supported by evidence from an event related potential study (ERP, Fujihara, Nagaeishi, Koyama, & Nakajima, 1998) which found that typical examples were categorized faster and more accurately than atypical examples.

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Given the robustness of the typicality effect, numerous models of typicality have been proposed to account for this effect. According to the feature comparison model (Rips et al., 1973; Smith et al., 1974; Smith & Medin, 1981), categorization is based on a two stage process. Typical examples and nonmembers need only go through the first stage of a category membership decision process, since the number of matches either exceeds a high criterion or falls short. Atypical examples, however, invoke the second stage since the first stage yields the number of matches between the two criteria. Categorization in the first stage involves judging the presence or absence of characteristic features, whereas the second stage proceeds on the basis of defining features alone.

According to prototype/family resemblance models (Rosch & Mervis, 1975; Hampton, 1979, 1993, 1995), a category is represented by a set of features which are shared by most but not all members of the category. The degree to which a given member possesses attributes in common with other members is correlated with the degree of typicality. Thus, typical items share more features with other members of the category while atypical members share fewer features with other members in the category. Category membership is computed based on a measure of similarity to a prototype, degree of feature match and through a threshold criterion placed on this feature-based similarity scale. Finally, according to exemplar models, a category is represented by particular instances that have been previously encountered (Heit & Barsalou, 1996; Komatsu, 1992; Smith & Medin, 1981; Storms, De Boek, & Ruts, 2000). A new item is judged to be an instance of the category to the extent that it is sufficiently similar to one or more instances stored in memory. Variations in typicality reflect varying degrees of similarity to stored examples of the category. Therefore, typical examples match with greater number of previously stored examples than atypical examples.

While typicality has received a great deal of attention in normal psycholinguistic experiments, few studies have investigated the effect of typicality of category exemplars in aphasia. Grossman (1980, 1981) tested the typicality model of semantic organization on fluent and nonfluent aphasic patients and right hemisphere damaged patients. Patients were required to name as many instances of a given superordinate category as possible in one minute. The absolute number of responses produced by the patient, the typicality rating of these responses and the frequency of occurrence of these responses were analyzed. The majority of the nonfluent aphasic patients' responses were in the central portions of the superordinates' referential field; the number of less central items provided was significantly fewer. In contrast, fluent aphasic patients produced fewer central responses than nonfluent patients, and often, also produced examples that did not belong to the category. Patients with left hemisphere insult produced fewer clusters of related items than patients with right hemisphere damage.

In another study, Grober, Perecman, Kellar, and Brown (1980) compared the performance on anterior (mainly nonfluent) and posterior (mainly fluent) aphasic patients and a control group on a task of typicality judgment. Patients were presented with pictures and printed words and were required to decide if the presented stimuli were members of a particular superordinate category. Latency data indicated that the normal controls tested were fastest to respond, while anterior aphasic patients were slowest to respond. In addition, typical items were responded to faster than atypical items by all three groups. Accuracy on judgment tasks dropped from 100% for typical members to 85% for atypical members for the anterior aphasic patients, while for the posterior aphasic patients, accuracy in judgment tasks dropped from 95% for typical members to 66% for atypical members. Posterior aphasic patients also demonstrated difficulty in judging the membership of unrelated items, with more errors when the items and superordinate category had some overlap.

While Grober et al. have provided preliminary evidence for abnormal access of atypical examples in Wernicke's aphasic individuals, these findings are yet to be replicated. Also, the characteristics of the aphasic participants involved in their study are not detailed, including whether or not the posterior aphasic patients presented with concurrent offline semantic deficits. The present experiment, therefore, aimed to further investigate the effects of typicality of category exemplars on category verification in patients with aphasia and reconcile the findings with current models of typicality. An online category verification task utilizing superordinate labels as primes and atypical, typical or nonmembers as targets was assessed in normal young, elderly, Broca's aphasic, and Wernicke's aphasic individuals. The present experiment differed from Grober et al.'s study in that superordinate category labels and typical and atypical examples belonged to animate categories. This was because typicality norms obtained from normal young and elderly individuals (Kiran & Thompson, in press) revealed that items at the boundaries of inanimate semantic categories often belonged to overlapping categories (e.g., *weapons*: *scissors*, *dart*, and *javelin* are also typical examples of categories like *tools*, *sports*). Hence inanimate categories were rejected for use in this experiment. The aim of this experiment was to identify differences in activation of typical and atypical examples within each participant group. In the present experiment, we also calculated the percentage advantage for typical examples compared to atypical examples across the four groups. We predicted all four groups to demonstrate a typicality effect (faster reaction times for typical compared to atypical examples). However, based on evidence from Grober et al. (1980) and Grossman

(1981), Wernicke's aphasic patients were predicted to demonstrate different patterns of activation compared to the other three groups.

2. Materials and methods

2.1. Participants

Nine normal young ($M = 21$ years, age range = 19 to 27 years), nine normal elderly ($M = 72$ years, age range = 60 to 85 years), seven Broca's aphasic individuals ($M = 58.2$ years, age range = 53 to 65 years), and seven Wernicke's aphasic patients ($M = 70.5$ years, age range = 63 to 81 years) participated in the experiment. The young and elderly participants were recruited from the Buehler Center on Aging Registry and from Northwestern University. All these participants had normal or corrected to normal vision, normal hearing, and had at least a high school education. Exclusionary criteria included neurological disorders such as stroke, transient ischemic attacks, Parkinson's disease, Alzheimer's disease, psychological illnesses, history of alcoholism, learning disability, seizures, and attention deficit disorders. Handedness was not controlled in these individuals.

The seven Broca's aphasic and seven Wernicke's aphasic patients were selected from the Northwestern University Speech and Language Clinic and the Aphasia and Neurolinguistic Research Laboratory subject pool and were recruited from stroke groups in the greater Chicago area. Several participant selection criteria were met in order for them to be included in the study: (a) diagnosis by a neurologist of a stroke in the left hemisphere (encompassing the gray and or white matter in and around the perisylvian area confirmed by a CT or MRI scan), (b) onset of stroke at least nine months prior to participation in the study, (c) at least a high school diploma, and (d) native speaker of English. Except one Broca's aphasic patient (MD), the remaining patients were all right-handed.

Pretesting measures were administered to the participants to ensure: (a) no hearing or visual impairment, and (b) diagnosis of aphasia as measured by calculation of Aphasia Quotient (AQ) from portions of the *Western Aphasia Battery* (WAB, Kertesz, 1982). Each Wernicke's aphasic patient ($M = 60.3$, range = 43.4 to 76.2) was matched for severity with a Broca's aphasic patient ($M = 59.5$, range = 30 to 81.6) based on their WAB AQ. Individual histories and performance on standardized language tests were shown in Table 1. Auditory comprehension of simple commands was assessed through the WAB auditory comprehension test, which revealed a subscore of 5 or higher for all patients. As a group, however, Wernicke's aphasic patients demonstrated greater difficulty with auditory comprehension ($M = 6.4$, range = 5.7 to 7.7) than Broca's aphasic patients ($M = 8.2$, range = 6.1 to 9.35). Naming performance was tested using the *Boston Naming Test* (Goodglass et al., 1983) indicating a varied performance across the two groups (Broca's group: $M = 35\%$, range = 0% to 80%; Wernicke's group: $M = 18\%$, range = 2% to 48%).

Semantic processing was assessed using selected subtests from the *Psycholinguistic Assessment of Language Processing in Aphasia* (PALPA, Kay et al., 1992)

Table 1
Individual histories and performance on WAB (Kertesz, 1982), BNT (Goodglass, Kaplan, & Weintraub, 1983), and selected PALPA (Kay, Lesser, & Coltheart, 1992) tests for seven Wernicke's and seven Broca's aphasic patients

	Age	WAB AQ	WAB-fluency	WAB-AC	BNT	PALPA-WPM	PALPA-synonym judgment	PALPA-semantic associates HI	PALPA-semantic associates LI	PALPA-VLD
Broca's aphasic patients										
EP	57	48.2	1	9.8	0	0.93	0.83	0.75	0.75	1
RN	65	41.8	4	6.7	0.05	0.93	0.72	0.67	0.13	0.92
JOC	64	78	5	9.45	0.7	1	0.93	0.8	0.8	1
JG	63	30	1	8.1	0	0.83	0.8	0.4	0.2	0.95
MR	56	59	5	6.1	0.16	1	0.82	0.8	0.4	1
MD	53	78.3	4	9.35	0.7	1	0.98	0.87	0.87	1
CH	50	81.6	6	7.9	0.82	0.98	0.97	0.8	0.87	1
Mean	58.29	59.56	3.71	8.20	0.35	0.95	0.86	0.73	0.57	0.98
Wernicke's aphasic patients										
RM	63	50.9	7	5.85	0.13	0.89	0.7	0.4	0.53	0.98
HJ	64	43.4	5	5.8	0.15	0.59	0.68	0.6	0	0.92
JA	72	70	8	6.8	0.08	0.66	0.67	0.53	0.4	0.9
RM	75	46.4	7	5.7	0.07	0.85	0.65	0.33	0.2	0.95
HS	76	59.8	6	6.4	0.02	0.51	0.68	0.33	0.4	0.97
DS	63	75.6	8	7.1	0.47	0.94	0.8	0.67	0.33	0.98
NH	81	76.2	9	7.7	0.32	0.98	0.79	0.8	0.4	1
Mean	70.57	60.33	7.14	6.48	0.18	0.77	0.71	0.52	0.32	0.96

Note. AC, auditory comprehension; WPM, word–picture matching; HI, high imageability; LI, low imageability; VLD, visual lexical decision.

which included word to picture matching, synonym judgment, and semantic associates that were either high or low imageable pairs. Although the subtests were administered using both auditory and visual stimuli, scores for the auditory and visual modality are collapsed and reported as an average of both tests, since no patient presented with a modality specific impairment. As a group, Broca's aphasic patients were more accurate on the word to picture matching tasks ($M = 95\%$, range = 83% to 100%) than Wernicke's aphasic patients ($M = 77\%$, range = 51% to 98%). Similarly, Broca's aphasic patients' performance on the synonym judgment task was superior ($M = 86\%$, range = 72% to 98%) to Wernicke's aphasic patients' ($M = 71\%$, range = 65% to 80%).

Broca's aphasic patients were also more accurate at judging high imageable and low imageable semantic associate pairs ($M = 73\%$, range = 40% to 80%, $M = 57\%$, range = 13% to 100%, respectively) than Wernicke's aphasic patients ($M = 52\%$, range = 33% to 80%, $M = 32\%$, range = 0% to 53%, respectively). Both groups, however, evinced visual lexical decision abilities within normal limits for real words and nonwords (Broca's group $M = 98\%$, range = 92% to 100%, Wernicke's group $M = 96\%$, range = 92% to 100%). All patients were able to read and comprehend single words which were tested through the reading subtest of the WAB and through written word-picture matching subtest of the PALPA (where the patients tended to read the word accurately but chose semantic related items).

2.2. Stimuli

Three animate categories and their examples were utilized in the present experiment. Stimuli used in the present experiment were developed as part of another study and are reported in detail elsewhere (Kiran & Thompson, in press). Briefly, one group of 20 normal young and elderly individuals (none of whom participated in this experiment) provided as many examples as possible for 12 superordinate categories (*vegetables*, *transportation*, *weapons*, *tools*, *clothing*, *furniture*, *sports*, *fish*, *fruits*, *birds*, *occupations* and *musical instruments*). Then, another group of 20 normal young and elderly individuals rated examples for each of the 12 superordinate categories on their typicality. A rating of 1 corresponded to the item being a very good example or fit of the category; a rating of 7 indicated that item was considered a very poor example; a rating of 4 indicated a moderate fit. Participants were also required to mark *U* for examples that were unfamiliar to them (Malt & Smith, 1982). Once the participants completed the task, average rating score, standard deviation, and median value for each example of each category was calculated across the 20 participants. Several exclusionary criteria were employed to remove problematic examples within each category which resulted in the following categories being eliminated: *occupations*, *transportation*, *sports*, *fruits*, *musical instruments*, *weapons*, *clothing*, *animals*, *furniture*, and *tools*. Three remaining categories (*birds, vegetables* and *fish*) were selected for the online category verification task.

In each of the three categories, the average typicality rating for each item was converted into a *z* score. The top 15 examples with the highest *z* scores (range = −1.2 to −.45) were considered typical examples, and the bottom 15 examples with lowest *z* scores (range = 1.3 to .01) were considered atypical examples within each category. In addition to the 30 examples within each category, 30 nonmembers belonging to additional superordinate categories were selected for each category. Across the 30 nonmembers, there were five typical examples from six inanimate categories (e.g., *transportation*, *tools*, *sports*, *furniture*, *weapons* and *musical instruments*). Typical examples of inanimate categories were selected since these examples have little or no overlap with members of the experimental categories (Rosch & Mervis, 1975; Smith et al., 1974).

In order to ensure that there were no differences in the written word frequency between the typical, atypical examples and the nonmembers for the three categories, a single 3 (typicality: typical, atypical, nonmember) × 3 (category: *birds*, *vegetables*, *fish*) ANOVA was performed on the written word frequency (Frances & Kucera, 1982). Results revealed no significant main effects for response type ($F(2, 175) = 0.06$, $p = .94$) or for category ($F(2, 175) = 0.02$, $p = .96$) indicating that there were no significant differences in written word frequency across the response type (typical, atypical, or nonmembers) or categories (*birds*, *vegetables*, *fish*) selected for the experiment.

Therefore, three experimental categories, each with 15 typical, 15 atypical examples (3 categories × 30 items = 90) and 30 nonmembers (3 categories × 30 items = 90) resulted in a total of 180 items. Each of these items was paired with a superordinate label during stimulus presentation (e.g., typical examples: *bird*: *robin*, *vegetable*: *tomato*, *fish*: *haddock*; atypical examples: *bird*: *penguin*, *vegetable*: *garlic*, *fish*: *piranha*; nonmember: *bird*: *anvil*, *vegetable*: *rifle*, *fish*: *boxing*). There were 90 "Yes" responses and 90 "No" responses for the instruction "Is (x) a member of (y)", where x was the target word and y was the superordinate category label.

The 180 word pairs were assigned to a stimulus list that was divided into five blocks of 36 pairs each. Each block had three superordinate-typical pairs, three superordinate-atypical pairs, and six superordinate-nonmember pairs from each of the three experimental categories. Within each block, the order of presentation of the pairs was randomized. The superordinate prime was presented for 750 ms, while the target remained on screen until the participant made the category verification decision. Inter Stimulus Interval (ISI) between the presentation of prime and target was 200 ms (Rosch, 1975) and Inter Trial Interval (ITI) was 1500 ms. A Compaq presario (PC) computer loaded with Superlab, Cedrus Corporation, Phoenix Arizona, was used to generate stimuli and collect data (reaction time and errors).

2.3. Procedure

Participants were seated in front of a computer with their nondominant hand placed on the keyboard. They were instructed that they would first see a superordinate category label followed by a word. Their task was to read each word pair and decide if the target word belonged to the preceding superordinate category label. Participants were instructed to respond as quickly and accurately as possible by pressing the "yes" response button on the keyboard, if they judged the target to be a member of the category, and "no" if it did not belong to the category.

2.4. Data analysis

Percent errors made for typical, atypical, and nonmembers for the three categories were calculated for the four participant groups. Then, mean reaction times (and standard deviations) for the typical, atypical items, and nonmembers of the three experimental categories were computed. Following group analyses, data for each group were separated and analyzed. The independent variables in the experiment were category (*birds*, *fish*, *vegetables*) and typicality (atypical, typical, and nonmembers) while mean errors and mean reaction times were the dependent variables. Errors were replaced by the mean errors for each typicality by category cell for the particular participant. Reaction times faster than 50 ms and slower than 3000 ms were eliminated from the data.

3. Results

3.1. Error proportion

The young participants made errors on 4.2% of their responses, while the elderly participants erred on 2.7% of their responses. The Broca's aphasic participants made errors on 8.67% of their responses, while the Wernicke's aphasic participants erred on 22.1% of their responses. Error percentages for each group were further calculated by category and by typicality (see Table 2). All groups demonstrated more errors on atypical examples than on typical examples (see Fig. 1).

A repeated measures ANOVA was performed on the mean errors with groups (young, elderly, Broca's, and Wernicke's aphasic individuals) as between subject factors, and typicality (typical, atypical, nonmembers) and category (*birds*, *vegetables*, *fish*) as within subject factors. A significant main effect for group ($F(3,681) = 97.57$, $MS_e = 1.46$, $p < .0001$), typicality ($F(2,681) = 47.36$, $MS_e = 0.710$, $p < .0001$), and category ($F(2, 681) = 9.8$, $MS_e = 0.147$, $p < .0001$) was observed. Significant interaction effects were noted for group and typicality ($F(6,681) = 3.71$, $MS_e = 0.05$, $p < .01$) and group and category ($F(6,681) = 3.73$, $MS_e = 0.05$, $p < .01$). Post hoc tests on the group effect revealed that Wernicke's aphasic patients made significantly more errors than the Broca's aphasic patients ($p < .0001$),

Table 2
Error percentage (*e*) for the four participant groups reported for category and typicality

	Typical (%)	Atypical (%)	Nonmember (%)	Group mean (%)
Young normal participants				
Birds	0.66	5.3	1.3	2.2
Fish	6	13.3	2	5.83
Vegetables	2.67	14.7	.66	4.67
Group Mean	3.15	11.1	1.34	
Elderly normal participants				
Birds	1.42	2.6	.6	0.44
Fish	1.33	10.7	3.3	1.57
Vegetables	2	4.7	1	.72
Group mean	1.59	6.03	1.67	
Broca's aphasic patients				
Birds	10.6	23	5.74	6.46
Fish	2.83	21	11	7
Vegetables	0	7.62	2.39	2
Group mean	4.7	17.2	6.36	
Wernicke's aphasic patients				
Birds	21	32.4	18	22.5
Fish	17.1	44.8	24.8	17.7
Vegetables	11.4	30.5	17.6	26.3
Group mean	16.2	34	19.2	

Values in each cell represent the proportion of errors compared to the total number of responses in that participant group.

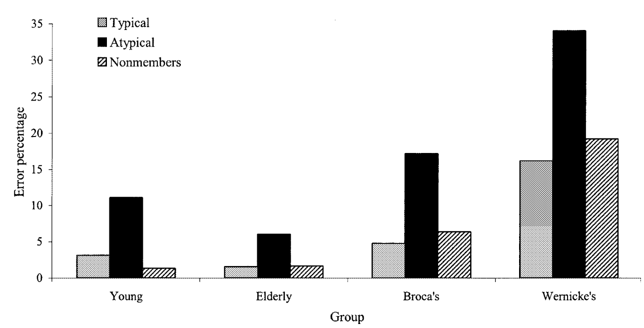

Fig. 1. Error percentage for typical, atypical examples, and nonmembers across the four participant groups. Errors for each category are collapsed within typicality.

elderly ($p < .0001$), and young individuals ($p < .0001$). Similarly, Broca's aphasic patients made significantly more errors than the elderly ($p < .0001$) and the young individuals ($p < .0001$). Post hoc tests on the main effect for category and typicality and interaction effects are not reported here since participant groups were separated and analyzed.

For each group, a repeated measures ANOVA was performed on the participants' mean error rates with typicality and category as within subject factors. A second repeated measures ANOVA was performed on the item mean error rates with typicality and category treated as between subject factors. For the young participants, a significant main effect for typicality [($F_1(2,75) = 16.9$, $MS_e = 0.081$, $p < .0001$), ($F_2(2,170) = 22.1$, $MS_e = 0.146$, $p < .0001$)], and category [(F, (2, 75) $= 3.70$, $MS_e = 0.017$, $p < .05$), ($F_2(2,170) = 4.80$, $MS_e = 0.0311$, $p < .05$)] was observed. No significant interaction effect was noted [($F_1(4,75) = 1.6$, $MS_e = 0.007$, $p > .05$), ($F_2(4,170) = 2.9$, $p > .05$)]. Post hoc tests on the main effect for typicality revealed significantly more errors on atypical examples than typical ($p_1 < .0001$, $p_2 < .0001$) and nonmembers ($p_1 < .0001$, $p_2 < .0001$). Post hoc tests on the main effect for category revealed significantly more errors on *fish* compared to *birds* ($p_1 < .05$, $p_2 < .01$).

For the elderly participants, a significant main effect for typicality [($F_1(2,72) = 6.8$, $MS_e = 0.012$, $p < .01$), ($F_2(2,170) = 3.08$, $MS_e = 0.024$, $p < .05$)] was observed. Main effect for category was only significant on subject analysis [($F_1(2,72) = 5.59$, $MS_e = 0.01$, $p < .01$), ($F_2(2,170) = 2.46$, $p > .05$)]. No significant interaction effect was noted [($F_1(4,72) = 3.8$, $p > .05$), ($F_2(4,170) = 2.9$, $p > .05$)]. Post hoc tests on the main effect for typicality revealed significantly more errors on atypical examples than typical ($p_1 < .01$, $p_2 < .0001$) and nonmembers ($p_1 < .001$, $p_2 < .0001$). Post hoc tests on the main effect for category revealed more errors on *fish* than *birds* on the subject analysis ($p_1 < .001$).

For the Broca's aphasic participants, a significant main effect for typicality [($F_1(2,54) = 6.88$, $MS_e = 0.09$, $p < .01$), ($F_2(2,170) = 13.11$, $MS_e = 220$, $p < .001$)] and category [($F_1(2,54) = 4.32$, $MS_e = 0.060$, $p < .01$), ($F_2(2,170) = 9.18$, $MS_e = 0.154$, $p < .01$)] was observed. No significant interaction effect was noted [($F_1(4,54) = 0.9$, $p > .05, F_2(4,171) = 2.19$, $p > .05$)]. Post hoc tests on the main effect for typicality revealed significantly more errors on atypical examples than typical ($p_1 < .001$, $p_2 < .0001$) and nonmembers ($p_1 < .01$, $p_2 < .0001$). Post hoc tests on the main effect for category revealed significantly fewer errors on *vegetables* compared to *birds* ($p_1 < .05$, $p_2 < .0001$) and *fish* ($p_2 < .0001$).

For the Wernicke's aphasic participants, a significant main effect for typicality was observed ($F_1(2,54) = 5.6$, $MS_e = 0.22$, $p < .01$), ($F_2(2,170) = 16.26$, $MS_e = 487$, $p < .0001$) while only the item analysis was significant for category ($F_1(2,54) = 1.0$, $p > .05$), ($F_2(2,170) = 3.84$, $MS_e = 0.110$, $p < .05$). No significant interaction effect was noted ($F_1(4,54) = 0.33$, $p > .05$), ($F_2(4,170) = 1.22$, $p > .05$). Post hoc tests on the main effect for typicality revealed more errors on atypical examples than typical ($p_1 < .05$, $p_2 < .0001$) and nonmembers ($p_1 < .05$, $p_2 < .0001$). Post hoc tests on the main effect for category revealed significantly fewer errors on *vegetables* compared to *fish* ($p_2 < .05$).

3.2. Mean reaction times

The second set of statistical analyses was performed on the mean reaction times collected. A repeated measures ANOVA was performed on the mean reaction times with groups as between subject factors, and typicality and category as within subjects factors. A significant main effect for group ($F(3,681) = 270.47$, $MS_e = 1.28$, $p < .0001$) typicality ($F(2,681) = 10.53$, $MS_e = 5.07$, $p < .0001$) and category ($F(2,681) = 3.77$, $MS_e = 1.79$, $p < .05$) was observed. A significant interaction effect was noted only for group and typicality ($F(6,681) = 2.72$, $MS_e = 1.29$, $p < .05$). Post hoc tests on the main effect for group revealed that Wernicke's aphasic patients were significantly slower than Broca's aphasic patients ($p < .0001$), elderly ($p < .0001$) and young individuals ($p < .0001$). Similarly, Broca's aphasic patients were also significantly slower than the elderly ($p < .0001$) and young individuals ($p < .0001$). Post hoc tests on the main effects for typicality and category and interaction effects are not reported since data for the four groups were separated and analyzed. For each group, a subject analysis and item analysis was performed on the mean reaction times. Table 3 reveals mean reaction times and their standard deviations for the participant groups for typical, atypical examples and nonmembers for the three categories.

For the young group, there were significant main effects for typicality across participants and items [($F_1(2,75) = 6.28$, $MS_e = 0.254$, $p < .01$), ($F_2(2,170) = 14.64$, $MS_e = .4158$, $p < .0001$)]. The main effect for category was significant only for items ($F_2(2,170) = 3.64$, $MS_e = .148$, $p < .05$) and no significant interaction effects were noted. Post hoc tests on typicality for both participants and items revealed faster reaction times for typical compared to atypical examples ($p_1 < .001; p_2 < .0001$) and for nonmembers compared to atypical examples ($p_1 < .001$; $p_2 < .0001$, see Fig. 2). No significant differences between typical and nonmembers examples were found indicating that participants were equally fast at rejecting nonmembers as they were at accepting typical category exemplars. Post hoc tests on the main effect of categories revealed faster reaction times for *birds* than *fish* ($p_2 < .05$) only for items.

Table 3
Mean RTs and standard deviations for category and typicality for the four groups

	Typical		Atypical		Nonmembers	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Young normal participants						
Birds	809	235	961	502	887	355
Fish	882	427	1090	526	930	384
Vegetables	914	330	1098	624	909	427
Group Mean	869	343	1050	555	910	391
Elderly normal participants						
Birds	930	267	1004	455	935	311
Fish	925	257	1149	538	970	274
Vegetables	864	178	1168	652	962	294
Group Mean	897	232	1073	464	954	284
Broca's aphasic patients						
Birds	1705	1095	2209	1263	1939	1245
Fish	1531	744	2459	1627	1922	1160
Vegetables	1311	592	1844	1001	1767	901
Group Mean	1515	847	2101	1210	1847	1040
Wernicke's aphasic patients						
Birds	2521	1058	2688	1058	2581	1103
Fish	2503	1340	2557	1220	2654	1167
Vegetables	2179	1175	2571	1250	2438	1133
Group mean	2338	1109	2597	1114	2485	1064

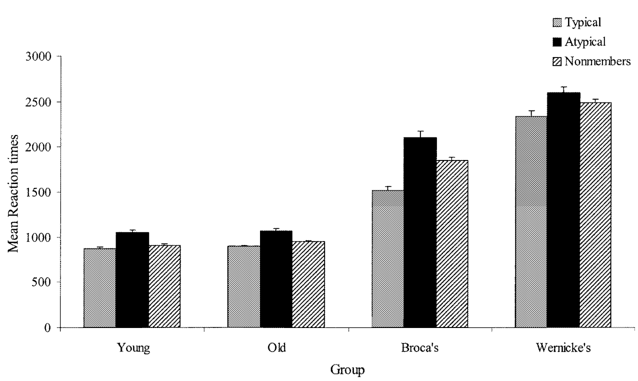

Fig. 2. Mean RTs and error bars for typical, atypical examples, and nonmembers across the four participant groups. RTs for categories are collapsed within typicality.

Analysis of the elderly participants revealed patterns similar to the young participants. Significant main effects were observed for typicality across participants and items $[(F_1(2,76) = 4.71,\ MS_e = 0.226,\ p < .01),$ $(F_2(2,170) = 8.47,\ MS_e = 0.4005,\ p < .001)]$ but not for category $[(F_1(2,76) = 0.06,\ p > .05),\ (F_2(2,170) = 0.155,\ p > .05)]$. No significant interaction effects were observed. Post hoc tests on typicality for both participants and items revealed faster reaction times for typical compared to atypical examples ($p_1 < .05; p_2 < .001$), and nonmembers compared to atypical examples ($p_1 < .05; p_2 < .001$, see Fig. 2). These findings indicated that the elderly participants, like young participants, were faster at accepting typical examples and rejecting nonmembers compared to accepting atypical examples.

Analysis of Broca's aphasic participants revealed significant main effects for typicality across participants and items $[(F_1(2,54) = 6.41,\ MS_e = 2.81,\ p < .001),$ $(F_2(2,170) = 20.924,\ MS_e = 4.84,\ p < .001)]$. A significant main effect for category was observed only for items $[(F_1(2,54) = 2.28,\ p > .05),\ (F_2(2,170) = 7.86,\ MS_e = 1.83,\ p < .001)]$ and no significant interaction effects between typicality and category was observed. Post hoc tests on typicality revealed significantly faster reaction times for typical examples compared to atypical examples ($p_1 < .01; p_2 < .0001$), and nonmembers compared to atypical examples only across items ($p_2 < .0001$) as well as for typical examples compared to nonmembers across items ($p_2 < .0001$, see Fig. 2). Therefore, like the young and elderly groups, Broca's aphasic patients accepted typical members faster than they accepted atypical members, and rejected nonmembers faster than they accepted atypical members. These patients, unlike their controls, however, also accepted typical examples significantly faster than they rejected nonmembers. Post hoc tests on the main effect of category was significant only for items and indicated that reaction times for *vegetables* were faster than *birds* ($p_2 < .001$) or *fish* ($p_2 < .001$).

Analysis of the Wernicke's aphasic participants revealed nonsignificant main effects for typicality $[(F_1(2,54) = 0.79,\ p = .95),\ (F_2(2,170) = 2.03,\ p = .13)]$ as well as for category $[(F_1(2,54) = 0.44,\ p = .64), (F_2(2,170) = 1.16,\ p = .31)]$ across items and participants. No significant interaction effects between category and typicality were observed. These findings indicated that

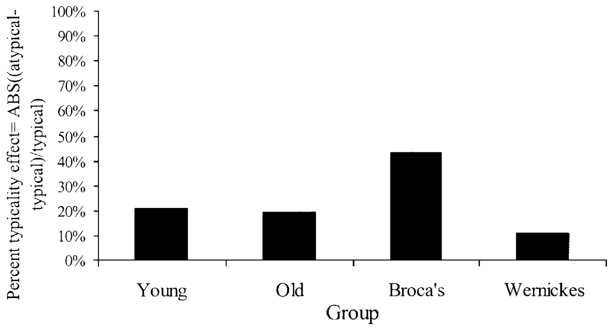

Fig. 3. Advantage for the typical example over the atypical example (in percentage) for the four participant groups.

Wernicke's aphasic patients were not significantly faster at accepting typical members compared to atypical members or at rejecting nonmembers than at accepting atypical members.

To further analyze the difference in reaction times between typical and atypical examples, the advantage for typical examples over the atypical examples was calculated. This effect, labeled *percent typicality effect*, was calculated as —(Mean Atypical – Mean Typical)/ Mean Typical— and thus normalized the data across the four groups. A positive value was observed, indicating that typical examples were faster than atypical examples across all the groups (see Fig. 3). The young and elderly participants demonstrated comparable percent typicality effects; typical examples were approximately 20% faster than atypical examples in both groups. Broca's aphasic patients demonstrated the largest typicality effect (45%) while Wernicke's aphasic patients demonstrated the smallest typicality effect (12%).

4. Discussion

Results of this experiment demonstrated that typical examples are processed faster and more accurately than atypical examples within a category. This effect was observed in the young and elderly individuals and in Broca's aphasic patients. Wernicke's aphasic patients demonstrated a different pattern from their normal controls in that these patients were more accurate but were not significantly faster at judging typical examples than atypical examples.

The present results demonstrated that all four groups made significantly greater errors on atypical examples than typical examples, a finding that is similar to other category verification reports (Grober et al., 1980; Fujihara et al., 1998; Larochelle & Pineu, 1994; Smith et al., 1974). While normal young and elderly individuals made relatively fewer errors, patients with aphasia, notably the Wernicke's aphasic individuals, made significantly greater errors. These results suggest that examples at the boundary of a category are more prone to error than items at the center of the category or nonmembers. Therefore, normal individuals are more likely to incorrectly reject extreme atypical examples than to incorrectly accept nonmembers. This hypothesis can be extended to patients with aphasia, where the category boundaries are less robust. Thus, the same strategy employed by aphasic patients results in greater errors than their controls.

The main finding of the present experiment was that the two normal groups and Broca's aphasic patients demonstrated significantly faster reaction times for typical examples compared to atypical examples. Patients with Wernicke's aphasia, however, did not demonstrate this phenomenon. These findings suggest that upon presentation of the superordinate category label, in normal individuals and at least in patients with Broca's aphasia, access to typical examples is more rapid than access to atypical examples. Notably, upon presentation of the category label, rejection of nonmembers is also more rapid than acceptance of atypical examples. Based on the percentage typicality effect that we calculated, a significant difference between typical and atypical examples roughly corresponded to an advantage of 20% faster reaction times for typical examples. Although Wernicke's aphasic patients demonstrated a positive advantage for typical examples (12%), this advantage was below 20% and was not statistically significant.

The findings of the young and elderly participants support previous experiments on normal individuals examining reaction times during an online category verification task (Hampton, 1979; Larochelle & Pineu, 1994; Rips et al., 1973; Smith et al., 1974). Findings of the aphasic patients partially support the results of a previous experiment investigating reaction times on an online category verification task (Grober et al., 1980). Like the present study, Grober et al., found that Wernicke's aphasic patients made greater errors on judging atypical examples, while the performance of the anterior aphasic patients was indistinguishable from that of their controls. Unlike the present study, however, controls, anterior and posterior aphasic patients presented with significantly faster reaction times for typical examples compared to atypical examples. However, closer inspection of Grober et al.'s data revealed only a significant main effect for typicality and no significant effects of typicality within each group. Therefore, it could be possible that, like the present experiment, results of the Wernicke's aphasic patients illustrated statistically nonsignificant trends of a typicality effect. Results of Broca's and Wernicke's aphasic patients also support the hypothesis of Grossman (1981) who suggested that unlike normal individuals, neither fluent nor nonfluent aphasic individuals employ a definition-like criteria for determining what can be included in the category. The nonfluent aphasic patients rely on comparison between the ideal example of the category and the presented example, thus producing mainly typical examples. On the other hand, fluent aphasic patients are unable to anchor the category to its typical examples, as they do not accord the names of the central instances of a category to any special status. The present results are also consistent with other reports of abnormal priming effects in fluent aphasic patients who indeterminately activate all potential neighbors of a phonological target despite maximal difference from the target (Milberg, Blumstein, & Dworetzky, 1988). Furthermore, results of these patients on the present online experiment correspond with their offline semantic processing deficits on the standardized language tests administered, indicating a broad underlying semantic impairment.

We now attempt to interpret the results of each participant group with reference to models of typicality. For the young and elderly individuals, greater accuracy and faster reaction times for typical examples and nonmembers compared to atypical examples observed in the present experiment support the premise of the feature comparison model (Rips et al., 1973; Smith et al., 1974). The model however, falls short of explaining why Broca's aphasic patients would demonstrate a larger than normal typicality effect. Similarly, the feature comparison model is inadequate to explain the results of Wernicke's aphasic patients. For these individuals, the model might predict impaired access to characteristic features, since typical examples were not accessed faster than atypical examples. However, in conjunction with the high error rates observed for atypical examples in these patients, these data could also suggest impaired access to the defining features of the category.

According to exemplar models of typicality, faster reaction times for typical examples are observed since typical examples activate greater number of similar stored examples than atypical examples (Storms et al., 2000). Exemplar models, however, are not clearly elucidated (Komatsu, 1992); at one extreme exemplars are thought to be abstractions of family resemblance representations. At the other extreme, exemplar representations may involve no abstractions and are essentially memory traces (Komatsu, 1992). This lack of specification of an exemplar representation makes it difficult to hypothesize abnormal activation of typical and atypical examples in Broca's or Wernicke's aphasic patients.

A more parsimonious explanation for the present experiment may be provided by family resemblance/prototype models (Hampton, 1979, 1993, 1995; Rosch & Mervis, 1975). As described before, according to prototype models, the degree to which a given member possesses attributes in common with other members is correlated with typicality. The most commonly occurring features of the category are represented as the category prototype. For the young and elderly individuals, faster reaction times for typical examples are due to the greater overlap in features between these examples and the category prototype. Nonmembers have no overlap with the category prototype and are responded to equally rapidly. Atypical examples have partial overlap with the category prototype and amongst other examples in the category and are, thus, responded to the slowest. Based on our results, we hypothesize that Broca's aphasic patients are over-reliant on the comparison process between the target and the category prototype. Therefore, typical examples which are more similar to the prototype, are responded to faster than atypical examples or nonmembers. Since atypical examples have little overlap with the prototype, they are responded to slower. This strategy on the part of Broca's aphasic patients results in fairly accurate judgments, as observed by their error rates, and accounts for the large advantage for typical examples (45% faster reaction times) over atypical examples.

We hypothesize that in Wernicke's aphasia, the effect of a widespread semantic impairment on processing of semantic categories is manifest in two ways. First, category boundaries are impoverished, resulting in greater errors on items at the boundaries. Second, access to the category prototype is diminished, resulting in an impaired comparison process of the target with the category prototype. Therefore, these patients are not significantly faster at judging typical examples and nonmembers compared to atypical examples.

An unexpected finding of the present experiment was that all four participant groups demonstrated greater errors *on fish* than the other two categories. Additionally, the Broca's aphasic group individuals demonstrated fewer errors on *vegetables* than the remaining categories. In the present experiment, we carefully selected three animate categories and no inanimate categories since differential processing between animate and inanimate categories has been reported (e.g., Caramazza & Shelton, 1998; Cardebrat, Demonet, Celsis, & Fuel, 1996; Silveri et al., 1997). Nevertheless, it appears that even in the domain of animate categories, certain categories are processed differently than others, perhaps reflecting the inherent familiarity of the category (Malt & Smith, 1982). These observations do not influence the interpretations of the present experiment, since we analyzed the three experimental categories separately, but raise questions for future research regarding the nature of differential processing of examples within animate categories.

Finally, while greater errors and longer reaction times for atypical examples are taken to indicate weaker association between these examples and the category prototype, these observations may provide more insight into the differential representation of atypical examples within a semantic category. We (Kiran & Thompson, in press) have demonstrated training naming of atypical examples resulted in generalization to typical examples in four patients with fluent aphasia. Training typical examples on the other hand did not result in generalization to atypical examples. These findings confirm the same observations by Plaut (1996) in a connectionist network simulation. We believe (Kiran and Thompson, in press) that generalization from atypical examples to typical examples occurs because atypical examples are more "complex" than typical examples as they are more dissimilar to one another with regards to semantic features. Hence, atypical examples collectively convey more information about the featural variation that can occur within the category than do typical examples. The results of the present experiment contribute to this complexity theory by illustrating that increased processing time and greater errors maybe additional indices of complexity within semantic categories and may have implications for other semantic concepts such as multiple meaning words and concrete/abstract words.

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