# Sense of Effort During a Lexical Decision Task: Resource Allocation Deficits Following Brain Damage

Heather M. Clark
*Veterans Affairs Medical Center, Iowa City*
*The University of Iowa, Iowa City*

Donald A. Robin
*Department of Speech Pathology and Audiology and National Center for Voice and Speech, The University of Iowa, Iowa City*

Individuals' perception of task difficulty (sense of effort) is thought to reflect resource requirements. As task complexity increases, more resources are allocated to a task, and greater effort is experienced. We investigated resource allocation in subjects with brain damage by examining sense of effort during a lexical decision task. Although subjects with no brain damage demonstrate strong relationships among task complexity, reaction time, and effort (Clark & Robin, 1994), consistent relationships were not always observed for subjects with a history of cerebrovascular accident or traumatic brain injury. These data suggest that subjects with brain damage may not be sensitive to task complexity and may require external cues to effectively allocate resources.

The ability to sense how hard the body or mind is working is known as "sense of effort." The high accuracy with which individuals can report sense of effort for both motoric and cognitive tasks is well documented (e.g., Gopher & Braune, 1984; Moray, 1982). Although much is known about what may be "sensed" when effort is perceived during motoric tasks (e.g., heart rate, activation of motor units) (Borg, 1978; McCloskey, 1981), only recently have researchers studied the underlying factors that contribute to sense of effort during *cognitive* tasks. Several investigators have suggested that sense of effort reflects the amount of processing resources expended during performance of a task (Clark & Robin, 1994; Gopher & Braune, 1984; O'Donnell & Eggemeier, 1986).

If sense of effort reflects and/or drives resource allocation, there are clear implications for the understanding of communication impairments exhibited by patients with brain damage. There are several studies suggesting that the linguistic performance deficits observed in aphasic patients may result from attentional capacity or resource allocation constraints (McNeil, 1982; McNeil, Odell, & Tseng, 1991; Miyake, Carpenter, & Just, 1995; Peach, Newhoff, & Rubin, 1993; Peach, Rubin, & Newhoff, 1994; Robin & Rizzo, 1989; Selinger & Prescott, 1994; Tseng, McNeil, & Milenkovic, 1993). The purpose of this study was to examine sense of effort during a lexical decision task in order to gain additional insight into the resource allocation abilities of individuals with brain damage. Our questions were:

1. Do individuals with brain damage report a higher sense of effort than do normal non-brain-damaged subjects?
2. Do individuals with brain-damage show a different pattern of effort in relation to task complexity than normal non-brain damaged subjects?

## Method

### *Subjects*

Eight right-handed subjects with a history of left cerebrovascular accident (CVA) or traumatic brain injury (TBI) participated in the study. The six CVA subjects and one TBI subject each had a single focal lesion in the left hemisphere, verified by CT or MRI. The other TBI subject had less focal damage, consistent with that etiology. Five subjects aged in range from 23 to 45, and the other three subjects were between the ages of 66 and 72. All subjects had one or more years of college education except for CVA5 who had a high school education. All subjects were tested at least 6 months after onset and demonstrated language impairments on a standard aphasia battery, including the Multilingual Aphasia Examination, Boston Diagnostic Aphasia Examination, and the Token Test [see Lezak (1983) for references to all tests]. Six subjects demonstrated mild to moderate language impairments, while two (TBI1 and CVA6) were more severely impaired. With the exception of TBI1, who showed moderate deficits, all subjects performed normally on a visuoperceptual/construction battery (Facial Recognition Test, Line Orientation Test, Complex Figure Test—Copy, Drawing to Dictation, and Three-Dimensional Block Design Test). Performance on the Wechsler Adult Intelligence Scale–Revised was within normal limits for all subjects tested (IQ scores were not available for subjects TBI1 and CVA1).

The performance of the experimental subjects was compared to that of 13 subjects without brain damage (Clark & Robin, 1994) who completed the same task described in this study. These subjects ranged in age from 20–36 (mean age 26.3) and averaged 17.5 years of education (range 12–20).

### *Stimuli*

Word stimuli for the lexical decision task were from Arvedson (1986). They included concrete (highly concrete, high in frequency, and relatively high imagery) and abstract (low in concreteness, low in frequency of occurrence, and relatively low imagery) real words, and pronounceable nonwords derived by changing 1–3 letters of the previously mentioned words. Previous studies (Arvedson, 1986; Clark & Robin, 1994) have demonstrated that the concrete stimuli elicited the fastest reaction times (RTs), followed by the abstract and nonwords, suggesting that task complexity was increased as expected by these manipulations. Stimuli were presented as a nondegraded or a degraded image, resulting in six levels of complexity (3 levels of linguistic complexity x 2 levels of degradation).

### *Instrumentation and Procedures*

Stimuli were presented using a computer with a modified mouse (separate *yes* and *no* buttons were wired in parallel with the right and left mouse buttons, respectively). After each item, perceived effort was reported by the subject on a rating scale that consisted of a line centered on the computer screen labeled 0–200. A cursor appeared on the center slash, and could be moved to the right or the left by corresponding movements of the mouse. Pressing of the left button selected a point on the scale, and the software recorded an integer from 0–200 corresponding to that point on the scale.

Initial instructions were followed by a practice session for both nondegraded and degraded items. When the investigator was comfortable that the subject clearly understood the task, the experiment continued. Each subject completed 100 trials (subject TBI1 completed an earlier version of the task which had only the 50 nondegraded trials). For each trial, response latency, accuracy, and effort rating were recorded. Separate analyses of variance and correlations were conducted on data obtained from correct responses from individual subjects (alpha = .05). For clarity of presentation, general patterns of performance will be highlighted, while results of statistical analyses are detailed in Table 1.

**TABLE 1. Summary of statistical analyses. RT = Reaction time; LC = Linguistic complexity; DL = Degradation Level; NW = Nonword; A = Abstract word; C = Concrete word; D = Degraded stimulus; ND = Nondegraded stimulus; NS = No significant differences.**

| Subject | Dependent Variable | Significant Effect | | Significant (*p* < .05) Comparisons |
|---|---|---|---|---|
| TBI 1 | RT | LC | *F*(2,45) 9.55, *p* = .004 | NW > C |
| | Effort | LC | *F*(2,45) 20.88, *p* = .001 | NW > A > C |
| TBI 2 | RT | LC | *F*(2,79) 8.52, *p* = .005 | A > C |
| | | DL | *F*(1,79) 16.25, *p* = .001 | D > ND |
| | | LC x DL | *F*(5,79) 1.22, *p* = .3021 | |
| | Effort | LC | *F*(2,79) 7.22, *p* = .0014 | NW > C |
| | | DL | *F*(1,79) .03, *p* = .8631 | D > ND (except NWs) |
| | | LC x DL | *F*(5,79) 1.5, *p* = .2297 | |
| CVA 1 | RT | LC | *F*(2,76) 5.58, *p* = .0055 | NW > C |
| | | DL | *F*(1,76) 1.28, *p* = 2616 | |
| | | LC x DL | *F*(5,76) .90, *p* = .4098 | |
| | Effort | LC | *F*(2,76) 6.34, *p* = .0028 | For ND: A, NW > C |
| | | DL | *F*(1,76) 1.22, *p* = .2735 | For D: NS |
| | | LC x DL | *F*(5,76) 5.38, *p* = .0065 | |
| CVA 2 | RT | LC | *F*(2,85) 11.93, *p* = .0001 | A > C, NW |
| | | DL | *F*(1,85) 12.19, *p* = .0008 | D > ND |
| | | LC x DL | *F*(5,85) .36, *p* = .6979 | |
| | Effort | LC | *F*(2,85) 90.48, *p* = .0001 | NW > A > C |
| | | DL | *F*(1,85) 66.51, *p* = .0001 | D > ND (except NWs) |
| | | LC x DL | *F*(5,85) 35.9, *p* = .0001 | |
| CVA 3 | RT | LC | *F*(2,86) 10.12, *p* = .001 | NW > C, A |
| | | DL | *F*(1,86) 12.19, *p* = .0008 | D > ND |
| | | LC x DL | *F*(5,86) 2.99, *p* = .0557 | |
| | Effort | LC | *F*(2,86) 19.68, *p* = .0001 | NW, A > C |
| | | DL | *F*(1,86) .76, *p* = .3952 | |
| CVA 3 | | LC x DL | *F*(5,86) .01, *p* = .9898 | |
| CVA 4 | RT | LC | *F*(2,89) 5.34, *p* = .0066 | A > C |
| | | DL | *F*(1,89) 15.39, *p* = .002 | D > ND |
| | | LC x DL | *F*(5,89) 1.19, *p* = .2338 | |
| | Effort | LC | *F*(2,89) 6.92, *p* = .0017 | NW, A > C |
| | | DL | *F*(1,89) 2.06, *p* = .1547 | |
| | | LC x DL | *F*(5,89) 1.9, *p* = .1554 | |
| CVA 5 | RT | LC | *F*(2,95) 17.13, *p* = .0001 | NW, A > C |
| | | DL | *F*(1,95) 10.53, *p* = .0017 | D > ND |
| | | LC x DL | *F*(5,95) 3.09, *p* = 0503 | |
| | Effort | LC | *F*(2,95) 48.17, *p* = .0001 | ND: NW > A > C |
| | | DL | *F*(1,95) 32.14, *p* = .0001 | D: NW, A > C |
| | | LC x DL | *F*(5,95) 13.34, *p* = .0001 | |
| CVA 6 | RT | LC | *F*(2,70) 2.39, *p* = .0999 | NS |
| | | DL | *F*(1,70) 42.75, *p* = .0001 | D > ND |
| | | LC x DL | *F*(5,70) 1.49, *p* = .2338 | |
| | Effort | LC | *F*(2,70) 4.71, *p* = .0123 | NS |
| | | DL | *F*(1,70) 41.94, *p* = .0001 | D > ND |
| | | LC x DL | *F*(5,70) 1.34, *p* = .2689 | |

## Results

### *RT*

Nearly all of the individuals with brain damage demonstrated longer RTs compared to normal individuals in most conditions (Figure 1a). However, similar to non-brain-damaged subjects, all subjects demonstrated significantly longer RTs when the stimuli were degraded compared to nondegraded stimuli (Figure 2), with the exception of subject CVA1 for whom degradation did not have a significant main effect.

Non-brain-damaged subjects demonstrated the fastest RTs in response to concrete word stimuli, followed by abstract words, and finally nonwords. There was a trend toward this pattern for five of the experimental subjects; however, only the largest differences reached significance. For the other three subjects, abstract words elicited the longest RTs.

### *Effort*

Subjects with brain damage reported effort ratings that were within the same range as those reported by non-brain-damaged subjects (Figure 1b). Of interest, two subjects rated their effort numerically *lower* than did non-brain-damaged subjects when stimuli were degraded. These subjects, in addition to two others, did not demonstrate a significant main effect of degradation for effort. For the other subjects, degraded stimuli were accompanied

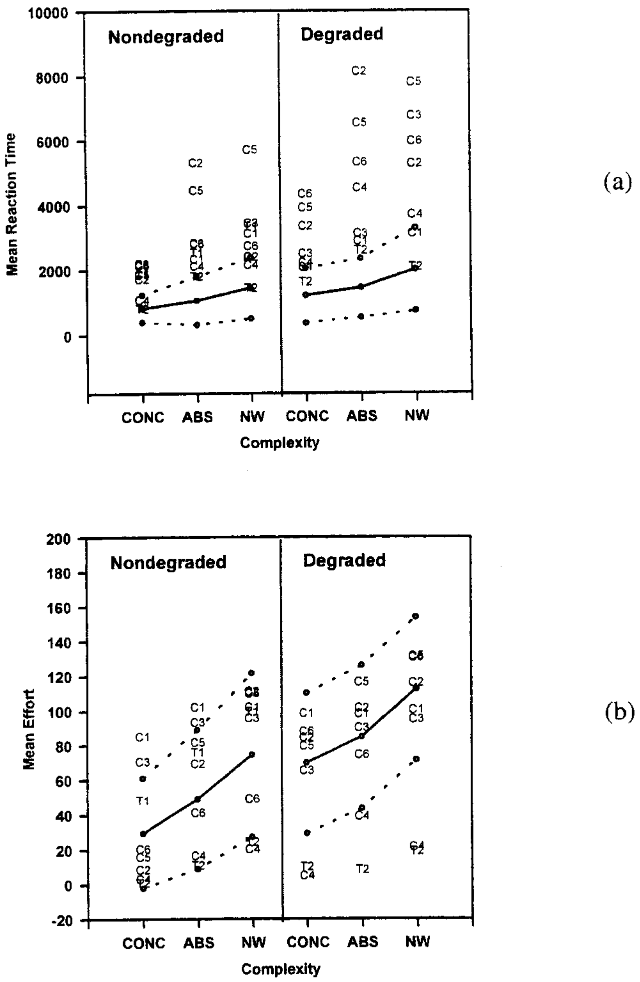

**FIGURE 1. (a) Mean Reaction Time. Solid line and dashed lines represent mean and ±1 *SD* reaction times for non-brain-damaged subjects. TBI and CVA subjects are represented by "T" and "C" respectively. (b) Mean Effort. Solid line and dashed lines represent mean and ±1 *SD* effort for non-brain damaged subjects. TBI and CVA subjects are represented by "T" and "C" respectively.**

by higher effort ratings in almost all conditions.

The effects of linguistic complexity on sense of effort were not consistent across subjects. In general, subjects reported increased effort as complexity increased, similar to each of the non-brain-damaged subjects. However, the differences in effort ratings across complexity levels were not as large, with only the largest pairwise comparisons reaching significance.

### *Relationship Between RT and Effort*

Since RT may also be an index of complexity, it is of interest to examine the relationship between sense of effort and reaction time. Non-brain-damaged subjects demonstrated a significant positive relationship between sense of effort and RT ($r$ = .5735; $p < .01$). The correlations between sense of effort and RT for individual subjects ranged from .2298 to .8020. Only one subject (CVA3) did not show correlations within the range reported for non-brain-damaged subjects.

Another way of describing the relationship between sense of effort and RT is the ratio of the amount of change in reaction time to the amount of change in effort. A high ratio indicates that large changes in reaction time corresponded to relatively small changes in sense of effort. A negative ratio indicates that the changes in reaction time and effort were in opposite directions (e.g., reaction time increased while sense of effort decreased).

Seven such ratios were calculated for each subject and compared with those obtained from non-brain-damaged subjects and are listed in Table 2. Ratios that fell outside ±1 standard deviation from the mean of non-brain-damaged subjects are starred. With the exception of subject TBI1 (for whom only two ratios were calculated), all subjects with brain damage demonstrated at least two ratios that fell outside the normal range, with four subjects demonstrating five ratios outside this range. In each case, the ratio is greater than 1 standard deviation above the mean for non-brain-damaged subjects. These results indicate that large changes in reaction time were associated with small changes in sense of effort for these subjects.

Five subjects demonstrated at least one negative ratio, indicating the changes in RT and effort were in opposite directions. Both possible patterns were observed (i.e., RT increased, effort decreased; RT decreased, effort increased). Four of the 13 non-brain-damaged subjects also demonstrated at least one negative ratio, resulting in 5/91 (5.5%) of all ratios being negative. In comparison, 14/56 (25%) of all ratios obtained from subjects with brain damage were negative.

To summarize, subjects with brain damage generally responded with extended reaction times during this lexical decision task. Effort ratings were not elevated relative to non-brain-damaged subjects and, in fact, were lower in some cases; moreover, the patterns of effort ratings were often unlike those of subjects without brain damage. Finally, the relationships between sense of effort and reaction time were different than were observed for subjects without brain damage.

## Discussion

This study examined whether subjects with brain damage report a higher sense of effort during a linguistic task than subjects without brain damage. The subjects reported here did not consistently report higher effort than non-brain-damaged subjects and, in fact, two subjects reported *lower* effort in some conditions. This result is in contrast to the anecdotal clinical observation that individuals with brain damage often report a high sense of effort associated with linguistic tasks.

Of particular interest are the abnormal patterns of effort observed with subjects with brain damage. Although seven of the eight subjects were sensitive to linguistic complexity, only one was sensitive to all three levels of complexity. Perhaps even more surprising is that four subjects were not sensitive to visuoperceptual complexity. These data suggest that sense of effort (and, by inference, resource allocation) for nonlinguistic processing may also be impaired for some subjects. This is consis-

Figure 2. Mean reaction time and effort for individual subjects.

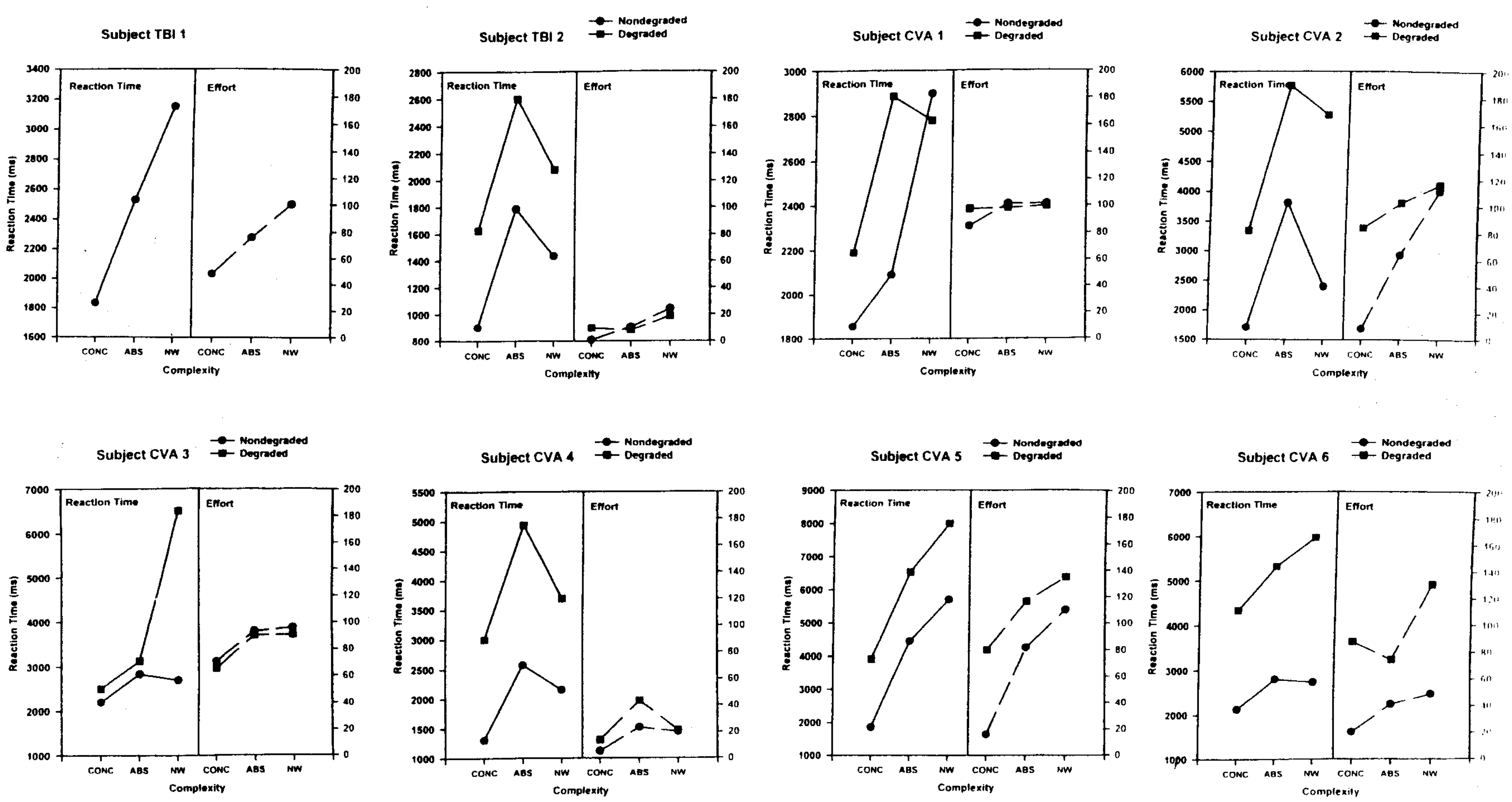

**TABLE 2. Ratios of change in reaction time to change in effort. Ratios which fell outside plus or minus one standard deviation from the mean of non-brain damaged subjects are starred.**

| | Abstract-Concrete | | Nonword-Abstract | | Degraded-Nondegraded | | |
|---|---|---|---|---|---|---|---|
| Subject | Nondegraded | Degraded | Nondegraded | Degraded | Concrete | Abstract | Nonword |
| Non-brain damaged<br>(Clark & Robin, 1994) | 24.57<br>(25.94) | 73.8<br>(183.94) | 21.4<br>(33.9) | -3.66<br>(91.7) | 13.96<br>(13.1) | 14.88<br>88 (17.2) | 13.75<br>(24.1) |
| TBI 1 | 25.1 | | 34.6 | | | | |
| TBI 2 | 89.24* | -549.1* | -25.98 | -48.61 | 78.76* | -42.3* | -119.72* |
| CVA 1 | 28.1 | -1709.21* | -7839.7* | 98.89* | 40.84* | -27.53* | 3.94 |
| CVA 2 | 59.14* | 275.6* | -69.05* | -196.8* | 21.55 | 3.28 | 594.9* |
| CVA 3 | 27.7 | 25.2 | 249.6* | 711.8* | -58.5* | -33.94* | -6624.8* |
| CVA 4 | 78.2* | 125.92 | 11.41 | 46.9 | 627.17* | 4.7 | 1252.4* |
| CVA 5 | 39.44 | 70.63 | 43.77 | 85.2 | 32.3* | 3.04 | 98.5* |
| CVA 6 | 32.5 | -72.07* | -7.93 | 11.59 | 32.69* | 75.51* | 39.66* |

tent with Robin and Rizzo's (1989) findings of attentional allocation deficits during a visuospatial attention task. Moreover, of the eight subjects reported on here, only two demonstrated significant main effects of both degradation level and linguistic complexity on effort ratings, whereas the other six subjects were sensitive to only one of these two complexity manipulations. These preliminary findings suggest that sense of effort may be differentially sensitive to different types of complexity manipulations.

At least two possible mechanisms may underlie the relationship between sense of effort and resource expenditure. It may be that resource expenditure is "sensed" when subjects report sense of effort (Gopher & Braune, 1984; O'Donnell & Eggemeier, 1986). In this case, the observation that sense of effort is not always related to task complexity for subjects with brain damage suggests that resources may not be allocated according to complexity by these subjects. The absence of a relationship between effort and complexity may reflect a mismatch between resource requirements and resource allocation, resulting in inefficient use of resources.

An alternative hypothesis is that sense of effort actually drives resource expenditure. If this is the case, an abnormal sense of effort would cause resource allocation to be disrupted. That is, a complex task that would normally be effortful and require a considerable amount of resources may be judged less effortful. The patient would strategically allocate an insufficient amount of resources to the task, and performance would suffer.

In conclusion, this study provides preliminary data that indicate that individuals with brain damage may demonstrate an abnormal sense of effort. These findings support the accumulating evidence of impaired resource allocation in individuals with brain damage (Arvedson & McNeil, 1985; Robin & Rizzo, 1989; Tseng, McNeil, & Milenkovic, 1993). Additional research is needed to further our understanding of the contribution of impaired sense of effort and/or resource allocation to performance deficits, and of the treatment strategies that may best remediate or compensate for these impairments.

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Contact author: Heather M. Clark, MS, Audiology and Speech Pathology Service 126, VA Medical Center, Iowa City, IA 52246

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