OHIO STATE UNIVERSITY WORKING PAPERS IN LINGUISTICS 38 (24-37)

# A Visual Half Field Study of Sentence Processing

**James Beale**
Cornell University
and
**Wayne Cowart**
University of Southern Maine

**Abstract:** This study attempts to exploit visual half field presentations of words in sentence contexts as an aid in the analysis of a cognitive function related to anaphoric processing. The function in question assimilates several kinds of information to resolve certain syntactic ambiguities. The experiments address the question whether all aspects of this linguistically complex function are supported by the language dominant left hemisphere. The evidence suggests that the anaphoric function is bihemispheric, i.e., that subfunctions supported by both hemispheres play a crucial role.

## 1. Introduction

A traditional concern among neuropsychologists and neurolinguists has been to associate cognitive functions involved in language with specific regions of the brain defined in terms of gross anatomy, differences of cell structure and patterns of interconnection, or possibly differences in local neurochemistry. The project discussed here is **not** an attempt to further this important enterprise, though it borrows neuropsychological methods and, if successful, would contribute to neuropsychological theory.

The goal of the exploratory research discussed in this paper is to exploit a feature of the mammalian visual system to reveal something of the logical structure of the processes that underlie sentence comprehension.

It might be thought that for an enterprise of this sort to succeed, it is necessary to have an antecedently established theory of how the neuropsychological manipulation we intend to use is related to language processing. While this is surely desirable, we do not believe it is necessary. We will assume that for a neuropsychological manipulation to be useful in the analysis of language processing it is only necessary that it produce some stable, repeatable effects that can be interpreted in linguistic terms. For example, suppose we did not know that there is something special about the left posterior frontal lobe, with respect to language. Suppose further that by applying a paste to the left scalp just forward of and above the ear we could temporarily produce some of the effects typically associated with Broca's aphasia. Though such a result would tell us something important about the brain, it would also be interesting from a psycholinguistic point of view, completely independently of its impact on neuropsychology. That is, the difference between the language functions a subject was able to exercise with and without the strategically

placed scalp paste would be informative not only about the role of the underlying cortical tissue, but also with respect to the logical organization of the processing system. In short, we hold that neuropsychological manipulations can, at least sometimes, be psycholinguistically interesting, even if their impact on the central nervous system is not well understood within neuropsychological theory.

Under these assumptions, it is of some interest that there is a standard technology in neuropsychology by which one may force one hemisphere to do all the initial processing of a linguistic stimulus. This technology is that of visual half-field presentations. The fundamental fact is that the mammalian visual system is organized in such a way that visual stimuli presented in the left visual field[1] are directly presented **only** to the visual areas of the right hemisphere while stimuli in the right visual field are presented only to the left hemisphere (Kelly 1985). This split in the visual system has been useful in discriminating the psychological functions of the two hemispheres (see Beaumont 1982).

There are, of course, structures, most notably the corpus callosum, that allow for rapid communication between the hemispheres. It appears, however, that even in the visual cortex the information that passes from one hemisphere to another is an interpreted, abstracted copy of the original stimulus, not a 'photographic' image of it. Thus, what one hemisphere is able to relay to another is limited to those properties of the stimulus that can be recovered by the resources that participate in the initial analysis of the stimulus, up to the level of abstraction relevant to interhemispheric communication. Furthermore, any communication between the hemispheres requires time, which may alter the way various kinds of information are integrated in a hemisphere that is applying internal resources to information received from the other hemisphere.

These facts suggest a case parallel to the paste experiment described above. Suppose that visual target words are presented following auditorily presented sentence contexts. Further suppose that these visual stimuli are presented exclusively to one or the other hemisphere for initial visual processing. If this manipulation has a linguistically interpretable result, then this technique can be useful for revealing the logical structure of the psychological processes of language regardless of what may or may not be independently known about linguistic differences between the two hemispheres.

Of course, there is perhaps more evidence for linguistic differences between the hemispheres than for any other difference (see Caplan 1987). This fund of information can be useful in attempts to interpret differences that might be detected, but, as we have argued, this need not be seen as a precondition for the successful exploitation of visual half-field technology. For present purposes, prior work on linguistic differences between the hemispheres contributes two things. First, the

[1] Roughly the half of the visual field that falls to the left of the point on which the eyes are currently focused.

elementary observation that in most adults the hemispheres are not equally able to support linguistic function, and that the left hemisphere plays the more central role in most adults. Secondly, this special role of the left hemisphere does not exclude participation of the right hemisphere, though the extent and nature of the contributions of the right hemisphere are not clearly established. This set of elementary observations opens the possibility that any result that exploits a rich complex of linguistic functions might in some way depend upon activity in both hemispheres. This in turn raises the possibility that procedures that in some fashion intervene in or disrupt normal modes of collaboration between the hemispheres may be able to reveal something of the way the logical problem the task presents is attacked by different functions. Looking at it another way, presenting a target to one hemisphere may have the effect of subtracting out, or limiting the participation of, resources resident in the other hemisphere. The effects of this subtraction should reveal something of how the resources that support the task are structured.

The work reported here constitutes a preliminary attempt to apply visual half-field technology to a question in sentence processing.

## 2. The Pronoun Bias Effect and its analysis

The background to the present investigation lies in previous work reported in Cowart and Cairns (1987) that argued for the presence of a notably asemantic antecedent-finding mechanism within the syntactic processing system. Cowart and Cairns reported two key results. On each trial the subject was required to quickly read aloud a verb form presented immediately at the offset of an auditorily presented sentence fragment. The evidence of several studies indicates that subjects spontaneously attempt to integrate the visual target word with the sentence fragment by the time they produce their voice response, though there is nothing in the procedure that requires this. The first result was that when subjects were required to read **is** at the end of fragments such as (1), response times were slower when the subject of the fragment was **they** rather than a plural NP such as **the birds**.

(1) As **the birds/they** soar gracefully over the field, flying kites. . .

This apparently reflects a tendency for subjects to interpret the ambiguous expression **flying kites** as a plural NP when **they** appears in prior context; this provides an antecedent for the otherwise uninterpreted pronoun, but yields an agreement anomaly when the subject is forced to read **is**. This effect of the pronoun subject of the clause on the subsequent reading of the verb was termed the Pronoun Bias Effect. The second result showed that in sentences such as (2), the Pronoun Bias Effect was not diminished when the grammatically optional interpretive link between the pronoun and the ambiguous expression produced an anomalous interpretation.

(2) If they eat a lot of oil, frying eggs. . .

Thus, it seemed that subjects made the referential link between the pronoun and the ambiguous expression on structural rather than semantic grounds, and even in spite of consequent semantic anomaly.

This phenomenon appears to be quite complex. It seems to involve solutions to at least three logically distinct problems, 1) the problem of finding an antecedent for the pronoun, 2) the problem of resolving the ambiguity of the ambiguous expression, and 3) the problem of assessing the agreement relation between the ambiguous expression and the following verb form (the target word).

On the evidence of Cowart and Cairns (1987) the mechanisms that deal with these three problems are able to operate and interact without allowing semantic or pragmatic concerns to block the coreference relation, at least as of the moment when subjects form their responses in that procedure[2]. What makes the result surprising is that general solutions to at least two of the problems enumerated above (antecedent finding and ambiguity resolution) would have to be sensitive to semantic and/or pragmatic information in many instances.

The interest of visual half field technology in relation to this problem is that it is not necessarily the case that all the linguistic cognitive resources the Pronoun Bias Effect engages are located in (or are most accessible via) the left hemisphere. As noted, both ambiguity resolution and antecedent finding commonly exploit semantic and pragmatic information relevant to the input, as well as syntactic analyses. On the general principle that the more complex a function is, the more of the brain's structure is engaged by its operation, these processes are good candidates for exploiting a broader range of brain structures. In particular, right hemisphere structures might be more heavily engaged than they would be if these processes were more narrowly syntactic in character. If the Pronoun Bias Effect is the product of some integration of resources across the hemispheres, then there is reason to hope that visual half field technology might be useful in beginning to tease apart those contributions.

There is also a somewhat more prosaic reason why the character of the Pronoun Bias Effect might change with lateralized presentations of the target words. In order for the effect to appear it is clearly essential that the subject identify the word presented and determine its morphological analysis (i.e., whether it is singular or plural). There is evidence that the two hemispheres differ in their ability to cope

---

[2] It should be noted that there is some evidence that semantic/pragmatic concerns may affect the subject's response. In particular, the magnitude of the Pronoun Bias Effect observed in the Anomalous Selectional condition in Cowart and Cairns' Experiment 2 is numerically much larger than in the Non-anomalous condition. The semantic/pragmatic anomaly thus seemed able to affect the subject's performance, but not in such a way as to block the coreference relation (without which there is no anomaly). Definitive evidence on this effect awaits further experimentation.

with these aspects of the task (see McAdams 1990, this volume, and references cited there). It may be that the Pronoun Bias Effect will differ by hemisphere of presentation because morphological information needed to implement it is extracted from the visual display less effectively by the right hemisphere than the left hemisphere.

One further aspect of the Pronoun Bias Effect should be mentioned. The discussion to here has viewed the Pronoun Bias Effect solely as a certain pattern of reaction time results. There is, however, a parallel phenomenon that has been observed with a judgment task. This phenomenon was first detected in a paper and pencil survey in which subjects were given printed forms containing sentence fragments such as those in (1) followed by two verb forms. The subject's task was to indicate which verb form made the better continuation of the fragment. When the subject of fragment was **you**, singular and plural forms were about equally acceptable, but there was a strong bias against singular verb forms when the subject was **they**. In Experiment 3 in Cowart and Cairns (1987) as part of each trial subjects indicated whether the verb form they had read aloud seemed to make a good continuation of the fragment. Judged acceptability of the verb form **is** declined dramatically with **they** subjects. Statistically, effects of these kinds have been markedly more robust than the reaction time results.

## 3. Experiment 1

The central problem addressed here is to discriminate the various cognitive resources that contribute to the Pronoun Bias Effect and to understand how their individual contributions are brought about and integrated. The specific prospect that motivates the present experiment, however, is the possibility that the effect might in some fashion depend upon higher order cognitive resources in both hemispheres. If both hemispheres do participate, then visual half field methods might be useful in addressing the more basic problem of analysis.

Even if the resources needed to implement the Pronoun Bias Effect are distributed across the two hemispheres, it is quite possible that the effect will persist in the face of lateralized presentations of the target word. There are many ways for this experiment to fail to detect bihemispheric participation even if that is the fact of the matter. Nonetheless, one possible outcome is that the pattern of reaction time effects that characterize the Pronoun Bias Effect[3] will not emerge at all with lateralized presentation. If this happens, and cannot be attributed to some uninteresting cause (e.g., low level visual system effects), then this will argue that the needed resources are bilaterally represented. There will then be grounds for using visual half field methods to try to understand how the component processes are differentiated, how they are distributed across the hemispheres, etc.

---

[3] That is, a slowing of naming responses to **is** when **they** rather than **you** (or another control NP) appears as subject of the context sentence fragment.

Another possible, perhaps more likely, outcome is that a pattern typical of the Pronoun Bias Effect will emerge when targets are presented to one hemisphere, but not the other. In this case it will matter a lot which hemisphere shows the effect. If the effect were apparent only with left visual field/right hemisphere presentations this would suggest that some crucial component of the processes supporting the effect is resident in the right hemisphere. Determining what the component was should lead to a better understanding of the processes that underlie the effect. The less interesting result would be a finding that the effect is apparent only with right visual field/left hemisphere presentations. This would neither add an interesting qualification to existing evidence locating language function primarily in the left hemisphere, nor would it encourage further work in this area with visual half field technology.

The basic methodological issue the experiments confront is the question whether interhemispheric communication will obliterate any hemisphere-specific effects. No attempts will be made here to correct for this problem. Further experiments could employ techniques designed to interfere with interhemispheric transfer of stimulus information.

## 3.1. Method

### 3.1.1 DESIGN

The design of the present study is derived from that of Experiment 1 of Cowart and Cairns (1987), modified for visual half-field presentation. The design involves two within-subject factors: Pronoun (the context fragment contains either **you** or **they**), and Visual Field (Left vs. Right Visual Field). This design is then replicated with the target verbs **is** and **are**. Stimulus materials were the 72 sentence fragments used in Experiment 2 in Cowart and Cairns in the non-anomalous conditions. There are thus nine trials in each of four experimental conditions for two different target verbs. To reduce the likelihood of subjects anticipating the target verbs 156 fillers were also included. Fillers contained a variety of sentence structures and verbs; filler verbs were limited to high frequency 2- and 3-letter verbs (as found in Francis and Kucera 1982). Twelve of these fillers were used as training stimuli, leaving 216 trials with the ratio of fillers to experimentals at 2:1.

### 3.1.2 PROCEDURE

Much current work on language-brain relationships makes some use of visual half-field presentations. However, the visual half field literature has little to say regarding the processing of words within a meaningful context, such as a sentence. The most relevant of this literature has focussed on lexical processing (e.g., Chiarello and Nuding 1987, Drews 1987, Howell and Bryden 1987, McAdams 1990, this volume). Apart from the addition of the auditory context, the procedures used here follow general practice in most respects.

All stimulus materials were recorded and digitized for computer presentation using OSU Linguistics Department computing facilities. Control of intonation was achieved by editing out the version of each VERBing NOUNs expression that was produced with **they** in the subject position of the initial subordinate clause. This same rendition of the ambiguous expression was then 'spliced' onto the end of both the **you** and **they** versions of the sentence fragment to insure that the two target verbs would be presented in the same intonational context regardless of what pronoun was used in the fragment.

An initial questionnaire was used to determine subjects' primary language, visual/auditory health, and handedness background (see below). Subjects were then seated in a booth approximately 30 to 45cm from a computer screen and given oral instructions describing the sequence of events on a typical trial. Subjects were asked to focus on a dot displayed at the center of the screen during the auditory presentation of the sentence fragment on each trial.

A computer presented auditory stimuli (sentence fragments) over a pair of earphones. Each sentence fragment was followed by lateral visual presentation of the target verb, 10 characters (26mm) to the left or right of the central dot; this placed the outer limits of the display at about 3 to 5 degrees of visual angle from the central dot. Exposure duration of the target verb was 100ms to insure that subjects did not have time to execute a saccade to bring the target word into foveal vision (Beaumont 1982). The computer timed the interval from the onset of the visual presentation of the target verb to the onset of the subject's phonation. Subjects then indicated whether or not the target verb provided a good continuation of the sentence fragment; this helped insure that subjects were attending to the sentence fragments. Response latency and judgements were recorded as dependent variables. This procedure required 45 minutes per subject.

### 3.1.3. SUBJECTS

Recent work by Bever, Carrithers, Cowart and Townsend (1990) and Cowart (1988) suggests that, in addition to previously recognized effects of personal handedness, there may be language processing effects associated with differences in familial sinistrality. Familial sinistrality is present when one or more of an individual's blood relatives are left-handed. Possible effects of this sort have been discussed in the neurolinguistic literature for some time (see Caplan 1987, for a review). There have also been reports suggesting that sex affects aspects of lateralization (see Caplan 1987). To partly control for possible influences of these sorts, only right-handed males without familial sinistrality in their primary and secondary families were used for this study.

Nine subjects meeting these criteria were drawn from the OSU Psychology 100 Subject Pool, thus allowing one subject per experimental condition, with one duplication.

### 3.2 Results

Cowart and Cairns (1987) found that Pronoun Bias Effect was best viewed as an effect on naming responses to **is**, rather than as an effect on responses to **are** or an interaction across the two verbs. This analysis will, in the main, follow their practice of considering responses to the two verb forms separately.

The **is** data is summarized in Figure 1. On visual inspection it appears that a slowing of responses to **is** in the presence of **they** appears only with left visual field/right hemisphere presentations.

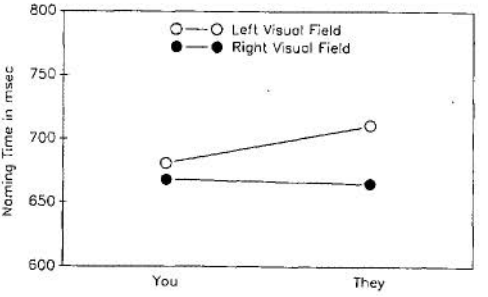


**Fig. 1:** Naming time to **is** by context pronoun and visual field in Experiment 1.

However, statistical analyses on these data reveal that they are highly variable and that the patterns they present are generally not reliable. In the **is** data there is neither a main effect of Pronoun nor an interaction between Pronoun and Visual Field. When the left visual field data is considered in isolation, the slowing of responses with **they** is significant, $F(1,8)=6.268$, $MS_e=646.5$, $p<.05$. There is also a main effect of Visual Field, $F(1,8)=8.828$, $MS_e=893.0$, $p<.02$, reflecting the overall slowing of responses to **is** with left visual field presentations. Little importance can be attached to these tests in the face of the nonsignificant interaction term.

In the **are** data there was a decline in naming times with **they** in context that seems consistent with earlier results. There is, however, no main effect of Pronoun, Visual Field, nor an interaction between these. The three way interaction among Pronoun, Verb, and Visual Field did not approach significance.

The judgment data reflecting subject's estimates of whether or not the verb form they read made a good continuation of the fragment they heard is summarized in Table I for both **is** and **are** targets. Visual inspection suggests that, much more than the naming responses, the judgment responses pattern very much like the results of earlier investigations. Relative to **you, they** reduces acceptability on trials with **is** targets and increases acceptability on trials with **are** targets.

The judgment data include a few outliers but no effort was made to correct for difficulties these may have introduced. The following tests must therefore be regarded with some caution.

When the target was **is** the decrease in acceptability from **you** to **they** contexts was reflected in a robust main effect of Pronoun, $F(1,8)=8.963$, $MS_e=3.375$, $p<.02$, which was mirrored by a significant effect of Pronoun in the data for the right visual field/left hemisphere, $t(8)=3.507$, $p<.01$. Though the pattern in the data for the left visual field/right hemisphere data was similar, it was not statistically reliable, $t(8)=2.061$, $p<.1$.

| | | you | they |
|---|---|---|---|
| Left | is | 59 | 38 |
| | are | 22 | 36 |
| Right | is | 69 | 49 |
| | are | 32 | 40 |

Table I: Percent of cases judged acceptable by Context Pronoun, Target Verb and Hemisphere to which target was initially presented in Experiment 1.

When the target was **are**, judged acceptability tended to improve from **you** to **they** contexts, but these effects are nowhere statistically reliable in this dataset.

When the **is** and **are** results are examined together in the context of a Pronoun x Verb x Visual Field design there is significant overall interaction between Pronoun and Verb, $F(1,8)=6.345$, $MS_e=2.736$, $p<.05$. A similar result appeared with right visual field/left hemisphere presentations, $F(1,8)=6.066$, $MS_e=3.59$, $p<.05$, but not with left visual field/right hemisphere presentations, $F(1,8)=4.209$, $MS_e=3.194$, $p<.1$.

There was also an overall decrease in acceptability with all targets presented to the left visual field/right hemisphere relative to targets presented to right visual field/left hemisphere, $F(1,8)=7.84$, $MS_e=0.347$, $p<.05$.

### 3.3. Discussion

The best summary of the naming time results is simply that nothing happened. There is no replication of the Pronoun Bias Effect nor any convincing evidence of some other pattern of response. It is perhaps a little surprising that the data from the left visual field/right hemisphere comes closer to replicating the effect than does the data from the right visual field/left hemisphere, but this difference is buried in noise and unlikely to replicate.

The judgment data is markedly more stable and more intelligible as well. It shows a pattern that is straightforwardly analogous to the Pronoun Bias Effect. **Is** is judged a poorer completion in the presence of **they** than **you**. While there is a trend in the opposite direction with **are** targets, it is not significant (as in previous studies). The significant Verb x Pronoun interaction further reinforces the impression that these data replicate earlier findings.

The only evidence of interhemispheric differences is that some of the judgment effects are robust with targets presented to the left hemisphere, but not the

right. But since the relevant interactions are not significant, there is no reliable evidence here of hemispheric differences.

## 4. Experiment 2

One possible account of the lack of hemispheric differences in Experiment 1 is that subjects were free to move their heads, which may have compromised the effectiveness of the visual half field manipulation. The second experiment replicates the first with improved procedure.

### 4.1. Method

#### 4.1.1. DESIGN AND PROCEDURE

The design of Experiment 2 is simply a replication of Experiment 1. To eliminate potentially confounding variables due to variations in the positioning of the subject's head, a viewing box was constructed for use in this study. This box places the screen at eye level and includes a headrest to minimize head movements. Distance to screen was thus held constant at 39cm. Target verbs were presented eight characters (21mm) to the left or right of the central dot, thus placing the outer limit of each target at 3 degrees of visual angle. Exposure duration of the target verb was increased to 150ms from 100ms because some subjects found the briefer displays of Experiment 1 hard to cope with.

#### 4.1.2. SUBJECTS

Eight subjects were drawn from the OSU Psychology 100 Subject Pool for this study. Subjects were once again right-handed males, without sinistral relatives.

### 4.2. Results

The is naming data are summarized in Figure 2. The patterns evident are unlike those of Experiment 1 and not like the Pronoun Bias Effect. But like Experiment 1, there is a great deal of variability in these data and the patterns are not reliable.

Tests on the is data show no significant main effects or interactions. The puzzling acceleration of naming time with

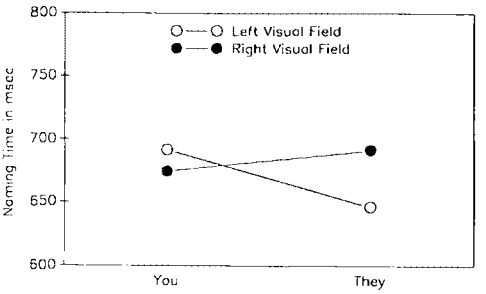


**Fig. 2:** Naming time to is by context pronoun and visual field in Experiment 2.

**they** in context in the left visual field/right hemisphere data yields a relatively large Pronoun x Visual Field interaction term, $F(1,7)=3.509$, $MS_e=2228$, $p\approx.1$. Within the left visual field/right hemisphere data the Pronoun effect is significant, $F(1,7)=6.915$, $MS_e=1190$, $p<.05$. This, however, is not a reliable measure in the absence of the interaction effect and is in any case exactly the opposite of what was observed in Experiment 1.

There were no significant effects or interactions in the **are** data or in analysis that combined **is** and **are** naming data.

The judgment data is again far more stable and intelligible. The results are summarized in Table 2. The pattern is like that of Experiment 1 except that the Pronoun effect seems larger with **are** targets and there is no evidence of the hemisphere differences seen in Experiment 1.

Within the **is** data there is a significant main effect of Pronoun, $F(1,7)=7.199$, $MS_e=1.567$, $p<.05$, indicating, as before, decreased acceptability with **they** in context rather than **you**.

Within the **are** data there is also a significant main effect of Pronoun, $F(1,7)=6.472$, $MS_e=3.786$, $p<.05$, reflecting an increase in acceptability with **they** rather than **you** in context. This effect is reliable in the data for the left visual field/right hemisphere, $t(7)=2.567$, $p<.05$, but not for the right visual field/left hemisphere, $t(7)=2.121$, $p<.1$.

An analysis that considers **is** and **are** data in the context of a Pronoun x Verb x Visual Field design shows a significant Pronoun x Verb interaction, $F(1,7)=14.121$, $MS_e=1.222$, $p<.01$, confirming that there is a reliable difference in the effects that the two pronouns exert on the two verbs. This effect is also independently significant in left visual field/right hemisphere data, $F(1,7)=10.343$, $MS_e=1.888$, $p<.05$, and the right visual field/left hemisphere data, $F(1,7)=7.631$, $MS_e=1.982$, $p<.05$.

Though the differences with **you** in context are small, the large difference in responses to the two target verbs when **they** is in context yield a significant main effect of Verb, $F(1,7)=9.304$, $MS_e=5.785$, $p<.02$. This is reflected in significant differences within the left visual field/right hemisphere data, $F(1,7)=8.326$, $MS_e=5.138$, $p<.05$, and the right visual field/left hemisphere data, $F(1,7)=7.027$, $MS_e=9.411$, $p<.05$.

| | | you | they |
|---|---|---|---|
| Left | is | 64 | 50 |
| | are | 17 | 33 |
| Right | is | 61 | 49 |
| | are | 18 | 40 |

**Table II:** Percent of cases judged acceptable by Context Pronoun, Target Verb and Hemisphere to which target was initially presented in Experiment 2.

### 4.3. Discussion

The naming results for Experiment 2 are as unstable as those for Experiment 1 and contradict the faint hints of effects that were evident in the first experiment. The appropriate conclusion is that these experiments have produced no evidence of the Pronoun Bias Effect in the naming results. Perforce they have also not revealed any differences in naming performance with materials presented to the left vs. right hemisphere.

Like Experiment 1, the results of the judgment task in Experiment 2 were far more stable than those for the naming task. The judgment results produced a statistically significant reflection of the Pronoun Bias Effect, but no reliable evidence of hemispheric differences. There was a slight tendency for certain effects to be statistically more robust with left visual field/right hemisphere presentations, but this is the reverse of the slight hemispheric differences noted in the first experiment.

## 5. Conclusions

The default expectation for this set of experiments is that the Pronoun Bias Effect will be evident when the target words are presented to the right visual field/left hemisphere and that the effect will be diminished or absent with presentations to the left visual field/right hemisphere. This did not occur. Rather, the Pronoun Bias Effect, as a naming phenomenon, was completely extinguished.

The disappearance of the Pronoun Bias Effect might be attributed to methodological error of some kind were it not that the pattern of judgment effects reported in Cowart and Cairns (1987) was neatly and robustly replicated here. Thus a case can be made that the naming effects also would have been as they were previously if ordinary non-lateralized presentations of the target words had been used.

The next step is obvious. Further experiments must demonstrate within the context of a within-subjects design that the procedure used here yields the Pronoun Bias Effect when the target is simultaneously available to both hemispheres, but not when it is initially available to only one.

If this can be done, there will be a *prima facie* case that the Pronoun Bias Effect is the product of a fast interaction among resources resident in both cerebral hemispheres. This in turn will provide opportunities to differentiate those resources and to associate each with a hemisphere.

### Acknowledgements

The experimental work reported in this paper was done as part of a B.A. Honors Thesis project by the first author under the direction of the second author.

The work was supported in part by a grant from the National Institutes of Health (1 R01 NS22606-01) to the second author. Additional support was provided to the first author as a grant from the Honors Program at Ohio State. This work benefitted substantially from a parallel project conducted by Brian McAdams, also reported in this volume, and from discussions with Gary Berntson and Ewen King-Smith. We are grateful to Phil Enny for invaluable technical assistance.

## References

Beaumont, J. G. (Ed.). (1982). *Divided visual field studies of cerebral organization.* Academic Press.

Bever, T. G., C. Carrithers, W. Cowart, and D. Townsend. (1990). Right-handers without left-handed relatives are more sensitive to grammatical structure and less sensitive to referential information than right-handers with left-handed relatives. In A. Galaburda (Ed.), *From Reading to Neurons.* Cambridge: MIT Press.

Caplan, D. (1987). *Neurolinguistics and Linguistic Aphasiology: An Introduction.* Cambridge, MA: Cambridge University Press.

Chiarello, C. and S. Nuding. (1987). Visual field effects for processing content and function words. *Neuropsychologia* **25(3):** 539-548.

Cowart, W. (1988). Familial sinistrality and syntactic processing. In J.M. Williams and C.J. Long (Eds.), *Cognitive Neuropsychology*, New York: Plenum.

Cowart, W. and H. S. Cairns. (1987). Evidence for an anaphoric mechanism within syntactic processing: Some reference relations defy semantic and pragmatic constraints. *Memory and Cognition* **15(4):** 318-331.

Drews, E. (1987). Qualitatively different organizational structures of lexical knowledge in the left and right hemispheres. *Neuropsychologia* **25(2):** 419-427.

Fodor, J. A. (1983). *The Modularity of Mind.* Cambridge, MA: MIT Press.

Francis, W. N. and H. Kucera. (1982). *Frequency Analysis of English Usage: Lexicon and Grammar.* Boston, MA: Houghton Mifflin Company.

Howell, J. R. and M. P. Bryden. (1987). The effects of word imageability on visual half-field presentations with a lexical decision task. *Neuropsychologia*, **25(3):** 527-538.

Kelly, J. P. (1985). Anatomy of the central visual pathways. In Kandel, E.R. and Schwartz, J.H. (Eds.) *Principles of Neural Science*, New York: Elsevier, pp. 356-365.

McAdams, B. (1990). Asymmetries in naming accuracy and in event-related potentials for laterally presented words of variable morphological complexity. This volume.

Stillings, N. A. (Ed.). (1987). *Cognitive Science: An Introduction.* Cambridge, MA: MIT Press.