Imageability Effects on Sentence Judgment by Right Brain-Damaged Adults

BACKGROUND

For decades, researchers assumed image generation was the province of the right hemisphere; it was not until 1983 that Erlichman and Barrett noted the lack of corresponding evidence (see Ganis, Thompson, Mast, & Kosslyn, 2003). While most recent studies of imagery generation have localized related processes to the posterior left hemisphere, conflicting results have left open the possibility that the right hemisphere also plays a role (for reviews, see Farah, 1995; Ganis *et al.*, 2003).

Meanwhile, several researchers have recently posited a connection between right hemisphere damage and impairment in reasoning from a theory of mind (TOM; e.g. Happé, Brownell, & Winner, 1999). Their studies, though designed to probe for impairment in TOM reasoning, raise the possibility of a RHD impairment in the comprehension of non-imageable stimuli in general. Stimuli in their studies, usually stories or cartoons, vary according to imageability: naturally, those that feature mental states include fewer imageable propositions than those that do not. The difficulty of adults with RHD in comprehending stimuli that hinge on mental states may simply be due to a deficit in processing stimuli that hinge on non-imageable "world knowledge." Future studies of RHD communicative deficits require a clarification of the relationship between RHD and imageable vs. non-imageable knowledge.

Farah, Levine and Calvanio (1988) have probed for an imagery deficit in a left hemisphere damaged patient using a sentence verification task developed by Eddy and Glass (1981). The task includes 16 sentences whose verification requires the generation of visual imagery, as judged by non-brain-damaged pilot subjects, and 16 whose verification does not. In their study, right hemisphere damaged control subjects verified the "High-" and "Low-imagery" sentences equally rapidly and accurately; however, the inclusion of only six control participants prevents any firm conclusions from being drawn. The study described below tests the performance of 34 participants with RHD on this task to provide further evidence about the effect of RHD on imagery generation.

METHOD

<u>Participants</u>- Seventy-two adults participated. Thirty-four had unilateral RHD due to CVA (confirmed by clinical CT and/or MRI scan reports); 38 were non-brain-damaged (NBD) controls without reported neurological impairment. All subjects were monolingual native speakers of American English with pre-morbid right-handedness and no familial left handedness via subject report. Hearing acuity was assessed via a pure-tone audiologic screening. There were no differences in demographic characteristics between groups (see Table 1).

<u>Task</u>- An auditory sentence verification task was used to assess potential effects of RHD on the processing of language stimuli that differ in imageability. Participants indicated whether each sentence was true or false on a two-button response box and were encouraged to respond as quickly as possible.

<u>Stimuli</u>- Experimental stimuli consisted of 18 High- and 17 Low-imageability sentences from Eddy & Glass (1981) (Table 2), each of which was false. Stimuli had been classified as High- or Low-imagery by Eddy and Glass according to whether pilot subjects had judged their verification to require imagery. High- and Low-imageability sentences were matched for noun frequency, mean auditory verification reaction times, truth agreement, and

comprehensibility. We constructed 36 filler stimuli similar in structure to the experimental stimuli; however, all were true.

Procedure – Participants were tested over 3 sessions with various tasks interspersed to maximally separate repeated presentations of stimuli. Stimuli were delivered via a notebook computer, through a headphone amplifier and high quality supraoral earphones at a comfortable loudness level selected by the participant. Participants responded by pressing one of two labeled buttons (Yes/No) on a manual response box. A timing mechanism generated and stored millisecond RTs. Prior to the experimental task, participants received extensive orientation and practice until RTs stabilized.

RESULTS

Descriptive data are presented in Table 3. Two-way ANOVA revealed that the RHD group was less accurate than the NBD group on both High and Low imagery items ($F(1, 70) = 6.40$, $p = .014$). In addition, both Groups were less accurate on High than on Low imagery items ($F(1, 71) = 25.02$, $p < .001$).

Two-way ANOVA on RTs for accurate trials showed the NBD group to respond more quickly than the RHD group ($F(1, 63) = 45.5$, $p < .001$). Crucially, a Group by Imagery interaction was also present ($F(1, 63) = 5.42$, $p = .023$). *Post hoc* t-tests showed that the NBD group was faster on Low imagery items than on High imagery items ($t(33) = 2.44$, $p = .020$) while there was no difference between High and Low imagery items for the RHD group ($t(30)=1.00$, $p = .325$, *ns*).

DISCUSSION AND IMPLICATIONS

In general, accuracy was higher, and response time lower, for Low-imagery than for High-imagery items. Subjects in the 1981 Eddy and Glass study exhibited the same pattern of results (although it is not evident from their paper whether the results were significant). This may be because Low-imagery items highlight “world -knowledge” more than High-imagery items.

Although NBD subjects’ RT for Low-imagery items was significantly faster than that for High-imagery items, this difference disappeared in the group with RHD. The group with RHD responded more slowly overall than NBD controls did, but the group difference in RT for High-imagery stimuli was significantly smaller than that for Low-imagery stimuli. We confirmed that this result was not due to a speed-accuracy tradeoff or to syntactic differences between stimulus sets.

This interaction suggests that RHD disproportionately slows access to world knowledge of the type that Low imagery items highlight. This result is also consistent with Farah (1995) and others’ assertion that image generation primarily involves the left hemisphere. Adults with RHD might rely disproportionately on imagery generation processes to comprehend or to solve problems because there is less competition between these and right-hemisphere processes. Furthermore, this result is consistent with our hypothesis regarding Theory of Mind studies: Individuals with RHD may exhibit an apparent deficit in comprehending mental state-rich stimuli because these stimuli hinge on non-imageable world knowledge. Researchers and clinicians in the future should consider the nature and extent of right hemisphere patients’ deficits in accessing world knowledge.

The above results, however, come with a qualification. In a re-assessment of stimuli, we noted that while all of the Eddy and Glass High-imagery stimuli could be solved through visual imagery formation, some could be solved through motor imagery formation as well. Previous research (e.g. Danckert *et al*., 2002) has suggested that adults with RHD, specifically those with parietal lesions, may have a deficit in generating motor imagery. Members of our lab therefore classified the High-imagery stimuli as either "motor" or "visual" with .88 inter-rater agreement; disputes were settled by a third party, resulting in a grouping of seven motor imagery stimuli and nine visual. A *post hoc* ANOVA on these stimuli revealed a Group x Imagery Type interaction ($F(1, 70) = 5.71$, $p=.02$; for descriptive data, see Table 4). As expected, t-tests indicated that subjects with RHD, while performing as well as NBD subjects on visual imagery items, had significantly Lower accuracy on motor imagery items. We conclude that the capacity of adults with RHD to generate visual and motor imagery should be investigated separately in future studies.

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TABLE 1. Demographic and Clinical Characteristics of Two Participant Groups

Characteristics	**RHD (n=34)**	**NBD (n=38)**
Age (years)		
Mean (SD)	64.74 (11.57)	60.45 (9.61)
Range	42-85	45-84
Gender		
Male	17	19
Female	17	19
Education (years)		
Mean (SD)	14.42 (2.96)	13.95 (2.27)
Range	10-22	12-20
Lesion site (from CT/MRI report)		Not applicable
Right cortical anterior	2	
Right cortical posterior	1	
Right cortical mixed	3	
Right subcortical	11	
Right cortical + subcortical	7	
Right MCA	9	
Not Available	38	
Lesion type (from CT/MRI report)		Not applicable
Thromboembolic	18	
Lacunar	3	
Hemorrhagic	13	
Not Available	38	
Months post-onset		Not applicable
Mean (SD)	52.91 (50.99)	
Range	4-167	
PPVT–R[a]		
Mean (SD)	157.38 (11.22)	162.97 (11.24)
Range	132-173	115-174
*Behavioural Inattention Test[b]		
Mean (SD)	136.79 (13.52)	144.03 (2.86)
Range	85-146	133-146
*Visual Form Discrimination[c]		
Mean (SD)	27.97 (3.61)	30.32 (2.22)
Range	20-32	24-32

*Judgment of Line Orientation[d]		
Mean (SD)	22.68 (5.09)	27.05 (4.26)
Range	9-30	16-33

Note. RHD = right hemisphere brain damage; NBD = non-brain damaged;

PPVT–R = Peabody Picture Vocabulary Test—Revised.

* RHD significantly poorer than NBD ($p < .05$)

[a]Dunn and Dunn (1981; maximum = 175).

[b]B. Wilson, Cockburn, and Halligan (1987; maximum = 146; neglect cutoff = 129).

[c]Benton, Hamsher, Varney, and Spreen (1983; maximum = 32).

[d]Benton et al. (1983; age and gender corrected score; maximum = 35).

TABLE 2. Low and High Imagery Experimental Stimuli (Eddy & Glass, 1981)

HIGH IMAGERY	LOW IMAGERY
A Star of David has five points.	There are six days in a week.
Tractors have two very large wheels in the front.	Geology is the study of living matter.
The hot water handle on a sink is on the right.	Middle age comes after old age.
The letter W is formed with three lines.	The best student is at the bottom of the class.
The stars on the American flag are blue.	A country has windows.
George Washington had a beard.	There are three human sexes.
A stop sign has seven sides.	Spring is a month.
The number 8 can be constructed from a single circle.	A novel is shorter than a novelette.
The accelerator on a car is the left pedal.	The introduction follows the story.
A tic-tac-toe game is drawn with five lines.	Salt is used less often than pepper.
A grapefruit is larger than a cantaloupe.	The prince will one day be queen.
The number 9 can be constructed from two circles.	A pound is heavier than a ton.
The dial on a telephone has nine holes.	Most watchdogs are Bulldogs.
A row boat comes to a point in the back.	Animals are stuffed by a toxicologist.
The symbol for degrees is an apostrophe.	Geology studies the history of mankind.
The letter A is formed with four lines.	A father buys children.
Yellow is darker than orange.	The US government functions under a three party system.
A right handed hitter places his right side toward the pitcher.	

TABLE 3. Accuracy and RT (means, SD's) for Low and High Imagery Stimuli

STIMULI	RHD	NBD
Accuracy - Mean, SD		
High Imagery	.79 (.14)	.87 (.13)
Low Imagery	.86 (.13)	.91 (.09)
RT (ms) – Mean, SD		
High Imagery	1245.54 (214.27)	971.92 (257.30)
Low Imagery	1294.58 (250.00)	876.00 (241.27)

TABLE 4. Accuracy and RT (means, SD) for Visual and Motor Stimuli

STIMULI	RHD	NBD
Accuracy- Mean, SD		
Motor	.75 (.20)	.88 (.17)
Visual	.85 (.12)	.88 (.12)
RT (ms) - Mean, SD		
Motor	1374.65 (481.72)	982.39 (362.15)
Visual	1633.97 (500.56)	1158.88 (403.72)