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Creative Cognitive Processes and Hemispheric Specialization

INTRODUCTION A battery of widely used tests were administered to 47 right handed, male, college undergraduates to examine the relationship between creative thought processes and hemispheric asymmetry. Hemisphericity was assessed by a dichotic listening free recall task. Factorial analysis of the students' scores on the creativity tests identified four factors: a verbal divergent search factor, a nonverbal divergent search factor, a verbal convergent search factor, and a nonverbal complexity factor.

The Verbal Search Factors as well as components of the Nonverbal Divergent Search Factor were related to hemisphericity. The present study also found that individuals with a right ear advantage produce large number of ideas, compared to individuals with a left ear advantage when responding to nonverbal stimuli. The later, however, generate equal or more sophisticated and complex creative solutions.

A relationship between creative problem solving abilities and hemispheric asymmetry has been proposed in numerous publications in the neurocognitive sciences literature (i.e., Gowan, 1979; Harpaz, 1983; Hellige, 1983). The precise nature of this relationship is unclear.

Rekdal (1979) and Martindale (1978) who used EEG and Conjugate Lateral Eye Movement procedures, demonstrated that individuals who are engaged in creativity tasks exhibit higher right hemisphere related activities. Other researchers (e.g., Uemura, 1980; Katz, 1983), using tachistoscopic and dichotic listening techniques, however, reported that creativity was positively related to left hemisphere advantage for verbal stimuli, whether presented visually or auditorially.

Some of the difficulties in correlating creative cognitive processes to hemispheric asymmetry may be due to the shortcomings of the different methodologies that were used to assess and scale hemispheric asymmetry. The complicated and multi-faceted nature of creativity and the tendency of researchers to lump together different cognitive processes into a single entity also contribute to this problem.

The present study was an attempt to overcome some of the identified limitations of previous studies by distinguishing between the various subdomains of creativity, and by carefully controlling extraneous variables, in order to study the individual and combined relationships between these sub-domains and hemispheric asymmetry.

The different creativity subdomains and their possible dependence on hemispheric asymmetry, were identified by administering a battery of widely used, relatively reliable creativity tests (Torrance, 1974). It was expected that Factorial Analysis of the scores of these tests will produce the same salient cognitive factors of creativity previously reported in the literature.

In particular, it was expected that factors representing convergent thinking and divergent thinking constructs (Belcher et al., 1981) would relate differently to lateralization. It was also expected that differentiation between tests that require verbal processing and tests that require nonverbal processing would emerge.

Several tentative predictions were made regarding the nature of the relationship between cognitive factors involved in creative processing and hemispheric asymmetry. It was predicted that factors which reflect divergent thinking would correlate with a left ear advantage while those that reflect convergent thinking, would correlate with a right ear advantage. It was also expected, however, that the scores in each factor would be affected by the amount of verbal as opposed to nonverbal processing involved in each of these factors. Finally, it was expected that neither the 'Process' subdomain or the 'Product' subdomain, present in the Torrances' subscores, would relate to hemispheric asymmetry.

METHOD

Subjects

Forty-seven English speaking, undergraduate, right handed males were recruited from an introductory psychology class at Wayne State University. The subjects came from a wide range of cultural, socioeconomical, and educational background. Students who scored below 45 on the Briggs and Nebes Handedness Inventory (Briggs & Nebes, 1975) or reported of a history of hearing deficits, neurological problems, or psychiatric disorders, were excluded from the study.

Materials

The ear advantage of the subjects was assessed using the Dichotic Listening Technique. Nonsense syllables (/ba/,/pa/) produced by Haskins Laboratories with a parallel resonance synthesizer (Repp, 1977) were presented with a Technics RD300 tape recorder and a Koss 5-C earphones with sensitivity of 10Hz to 25Hz frequency response. All syllables in the cassette were 300 msec long, had no initial outburst, and had a constant fundamental frequency (90Hz). Voice onset time (VOT) for all syllables remained constant. The intensities of the two auditory channels of the headphones were fully equalized.

The subjects' creative cognitive skills were assessed using a battery of pencil and paper tests. The criteria for selecting these tests were adopted from Katz (1983). These tests make it possible to distinguish between various subdomains of creativity, and each of them has some theoretical and empirical claim to validity and reliability:

Torrance test of Creative Thinking: Verbal Form A.

This test consists of seven subtasks from which three scales are derived: fluency (FLU.V), Flexibility (FLEX.V) and Originality (ORIG.V) in the verbal processing. The test exhibits strong inter-rater and test-retest reliability (Torrance, 1974, pp. 35-47). It correlates well with Guilford's Divergent Thinking Tests (Treffinger et al., 1986) but correlates minimally with measures of intellectual abilities (Dellas & Gaier, 1970, p. 57).

Torrance Test of Creative Thinking: Figural Form B.

This test consists of three subtasks, from which four scales are derived: Fluency (FLU.F), Flexibility (FLEX.F), and Originality (ORIG.F) in figural (nonverbal) processing. Three of these scores are similar to those in the Verbal Test. In addition, the test yield an Elaboration score which reflects a person's ability to "develop, embroider, embellish, carry out, or otherwise elaborate ideas." Scores on these tasks exhibit similar psychometric properties as the tasks in Torrance's Verbal Form A (Torrance, 1974).

Remote Association Test (RA).

In this test the subjects are asked to find the similarity shared by a set of items. For example, the word linking "surprise", "line" and "birthday" is "party". This test was criticized because of its weak theoretical basis and moderate correlation with between tests of intelligence (r = 0.30 to 0.40). However, Mednick & Mednick (1967) and Katz (1984) argue, on the basis of often replicated findings, that this test differentiates people judged by their peers as creative from those judged non-creative.

Welsh Revised Art Scale (WAS).

Barron & Welsh (1952), developed a test to assess artistic preferences with items consisting of drawings. They reported that artists preferred complex asymmetrical figures, whereas non-artists preferred the simple symmetrical ones. Thus, the WAS scores are considered to be a general measure of Cognitive Predisposition for Complexity. Subsequent research confirmed the reliability of the test and demonstrated that the tests identifies highly creative subjects, regardless of the field of expertise (Welsh, 1975).

Verbal Closure (VC).

Following Katz (1984), this test was included in the study as it claimed to predict production and evaluation (Hettema, 1968; Ohnmacht et al., 1970) skills that suggest cognitive flexibility: a variable that presumably underlies creative performance. The Verbal Closure employed in the study is the Hidden Words test, taken from the kit of Factor-referenced Cognitive Tests (Ekstrom et al., 1976).

DESIGN & PROCEDURE

Subjects were first asked to fill out the Biographical Information Form and Handedness Inventory. Then, the subjects listened to the Dichotic Listening cassette, and were asked to report verbally what they heard. After 25 presentations, the channels were reversed and counterbalanced. The number of correct identification of either right or left ear stimuli was recorded on an Auditory Response Chart. An Ear Advantage Index (EAI) was then computed by the equation:

$$EAI = \frac{RE}{RE + LE}$$

where RE is the number of correct identification of right ear stimuli and LE is the number of correct identification of left ear stimuli. As reported by Hellige (1983a), this index, which was first used by Krashen and Hartman (1979) correlated with the overall accuracy of the method.

In the third part of the study, the subjects completed the verbal and figural tests of Torrance, the Verbal Closure (VC) test, the Welsh Revised Art scale (WAS) and the Remote Association Test (RA). The order of completion of the above tests was counter balanced.

RESULTS An Orthogonal Transformation-Varimax analysis performed on the 5 tests and their resultant scores identified a set of four factors. The calculated communality scores (Nunnally, 1978, p. 347) also suggest that the four factors account for about 75% of the explained variance proportion. The results therefore indicate a strong factor solution. The loading of the scores in the various scales onto the factors shown in Table 1. One sees that the scores that loaded onto factor 1 are those in the Torrance Tests of Creative Thinking -Verbal Form A (FLU.V, FLEX.V, and ORIG.V), which assess the quantitative and qualitative ability of the subject to divergently produce ideas, after being given complex verbal stimuli as a starting point (a minimum loading of 0.4 was used to define significance in tests that have loaded onto the different factors).

The scores that loaded onto factor 2 are those gained in the Torrance Tests of Creative Thinking - Figural Form (FLU.F, FLEX.F and ELAB.F), which assess the qualitative ability of the subject to produce divergent ideas, after being given complex nonverbal stimuli.

Although the factors generated by Orthogonal solutions are ideally expected to be independent, *Factor 1* and *Factor 2* were found in the analysis to be moderately correlated ($r = 0.28$). This correlation is not surprising, as the scores in the Verbal and Figural scale of the Torrance Tests which loaded significantly onto these factors are also moderately correlated probably because all the Torrance Tests are related to divergent thinking (Torrance, 1974). (For a detailed description of the analysis see Anastasi 1968, p. 326). Thus, Factor 1 and Factor 2, which account for 37% and 30% of the solution variance, were termed the *Verbal Divergent Thinking Factor*, and the *Nonverbal Divergent Thinking Factor* respectively.

The scores that loaded onto *Factor 3*, are from the RA and VC tests. These tests ask the subjects to examine and formulate responses that involve a cognitive search of verbal information as well as a convergent logical search of acquired knowledge. Consequently, this factor may be termed a *Convergent Verbal Search Factor*. This Factor accounts for 17% of the solution variance. A similar factor was identified by Belcher et al (1981).

TABLE 1 Orthogonal Transformation Solution - Varimax

Test	Rotated Factor Loading			
	Factor 1	Factor 2	Factor 3	Factor 4
VC	-.03	-.16	.79*	-.25
RAT	-.08	.23	72*	.34
WAS	.08	-.01	.03	.87
FLU.V	.94*	.22	-.08	.07
FLEX.V	.95*	.12	-.05	.02
ORIG.V	.96*	.07	-.02	.11
FLU.F	.25	.80*	.08	-.21
FLEX.F	.01	.88*	.12	.06
ORIG.F	.25	.48	-.31	.47
ELAB.F	.13	.71*	-.18	.21

* Significant loading at $p < 0.01$

Factor 4 is primarily determined by scores in the WAS test and in other nonverbal tests. It accounts for 16% of the total variance of the solution. These tests involve a search in the nonverbal domain and assess differences in cognitive complexity of nonverbal stimuli. Therefore this factor may be termed a *Nonverbal Complexity Factor.*

As seen in Table 1, only one of the ten scores, the Originality Score in the Figural Subscales, loaded more or less evenly on all factors. This score assesses the ability of individuals to produce non-obvious, yet appropriate ideas.

The distinctive loadings of the various scores onto the four factors support the basic premise of the study, that it is necessary to distinguish between the various creativity subdomains and to avoid using an overall creativity index.

Using the factors scores weights, the individual standardized scores of the subjects in each of the factors were calculated. The correlations between these scores and the Ear Advantage Index (EAI) were also calculated. A regression analysis demonstrated that Factor 3 correlated significantly with EAI ($r = 0.41$ $p = 0.01$)[1]. The other factors did not correlate significantly with this index. The correlation of Factor 3, the Convergent Verbal Search Factor, and EAI supports the prediction made at the onset of the study, that the Convergent Verbal processes should correlate with a right ear advantage. On the other hand, no significant correlations were found between other factors and EAI.

In the second part of the analysis, the mean scores in the various creativity scores of the extreme groups, namely the groups that received EAI scores larger then a half standard deviation below and above the means, were calculated. The correlations

[1] Factor 3 and EAI remained significantly correlated ($r = 0.27$ $p < 0,05$) when the outlyers of the EAI were removed.

between the mean scores of these groups in the creativity tests and their EAI were also computed and are presented in Table 2. The results of this analysis make it possible to grossly assess the dependence of scores that load onto the four factors on the ear advantage index.

TABLE 2 Correlation Between Creativity Scores and Extreme Ear Advantage Index Scores

Test	Point by Serial Correlation	P
RAT	0.304	0.066
VC	0.210	0.038
WAS	0.21	0.151
FLU.V	0.1	0.646
FLEX.V	0.11	0.624
ORIG.V	0.21	0.345
FLU.F	0.45*	0.023
FLEX.F	0.41*	0.033
ORIG.F	0.37*	0.042
ELAB.F	0.21*	0.269

* The co-efficient is significant in the 95% level.

For the extreme groups mean scores that loaded onto Factor 1, the Verbal Divergent Thinking Factor slightly higher scores were obtained by the group with the right ear advantage. However, as seen from Table 2, these trends are insignificant. The results are consistent with the findings of an overall insignificant correlation between Factor 1 and EAI.

The mean extreme groups scores in the scales that load onto Factor 2 are shown in Figure 1. The dependence of these scores on EAI appears to be more pronounced and, indeed, the correlations between these scores and EAI are significant, as shown in Table 2. It was shown earlier that the correlations between the scores in Factor 2 and EAI are insignificant. The lack of correlation between the factor and EAI may be attributed to the findings that the dependence of on EAI of scores that loaded onto Factor 2 is not uniform. While the means scores in the Fluency, Flexibility, and Elaboration subscales for the group with a left ear advantage were smaller then the scores for the group with the right ear advantage, the scores in the originality subscale were higher for the group with the left ear advantage.

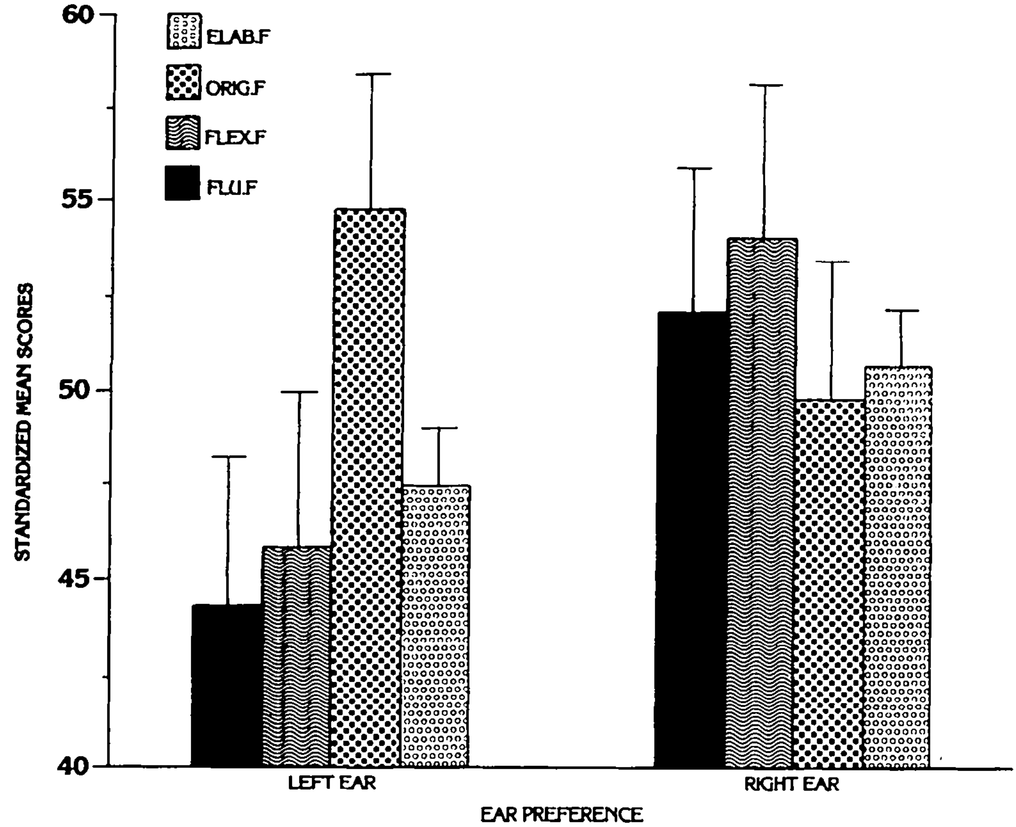

Figure 1. Mean Scores for FLU.F, FLEX.F, ORIG.F AND ELAB.F for the left and right ears.

The group with the right ear advantage achieved a higher score in all the subscales which loaded significantly onto Factors 3 and 4. However, only the dependence of the scores in the scales that loaded onto Factor 3 was significant, and almost significant. Since the trend of these two subscales were uniform, it produced a significant positive dependence of factor 3, on EAI.

It is also noted that the scores in the Figural Originality Subscale loaded negatively onto Factor 3 (a load coefficient of -0.31). Since the dependence of the scores in this subscale was also negative, it has also slightly contributed to the positive dependence of Factor 3 on EAI.

It was proposed earlier that a difference might exist between the dependence on hemispheric laterality of scores in the verbal versus the nonverbal subscales of each category. To examine the validity of this proposal, the dependence of indexes describing the percentage of verbal scores out of the total scores for the scales of Originality Fluency and Elaboration tests were calculated. This was achieved by using indexes that correspond to the Originality and Fluency Subscales [(Orig.V/(Orig.V = Orig.F)] and (Flu.V/Flu.V = Flu.F)]. Correlation analysis shows that the Originality index strongly depends on EAI ($r = 0.31$ $p = 0.05$). The correlation between the other indexes and EAI were, however, insignificant.

DISCUSSION The purpose of the study was to examine the relationship between a number of creativity subdomains and hemispheric asymmetry. A battery of tests was selected that was purported to assess both 'Process' and 'Product' variables as well as to distinguish between verbal and nonverbal processes that underline different creativity tasks. Factorial analysis of scores in subscales defined by these tests identified four factors which accounted for 75% of the total variance, indicating a strong factorial solution. Factor 1 and Factor 2, the most robust factors, comprised of the Torrance creative thinking subscores for the verbal and nonverbal (Figural) subdomains respectively. These tests involve divergent thinking thought processes, which has led to the labeling of two factors as *Verbal Divergent Search Factor* and *Nonverbal Divergent Search Factor.* The third factor generated was primarily loaded by the verbal convergent thought processes and was thus labeled a *Convergent Verbal Search Factor.* Factor 4, was primarily loaded by the Welsh Art Scale, which assesses cognitive nonverbal complexity. It was also slightly loaded by the figural Originality subscale, that is related to complexity, and was thus labeled as a *Cognitive Complexity Factor.*

The calculated correlations between the four factors and the ear advantage index, EAI, and between the tests that loaded onto each of the factors and EAI suggest several interesting conclusions. First, it is concluded that only the Verbal Convergent Search Factor depends significantly on hemisphericity as defined by EAI ($r = 0.41$ $p < 0.01$). Scores on this factor were found to be higher for subjects with a right ear advantage. This significant finding is consistent with previous proposals that had associated complex verbal processes with left hemisphere activities (Gazzaniga, 1970; Hellige, 1983a; Rahmani, 1987), as well as with previous suggestions that convergent thinking is also associated with increased left hemisphere activities (Springer & Deutsch, 1981). Apparently, the effects of verbal processing and convergence, have caused this factor to be significantly correlated with hemisphericity and to be larger in individuals with a right ear (left brain) advantage.

Neither the verbal nor the nonverbal Figural Divergent Thinking Factors exhibited correlations with hemisphericity. These results are consistent with those of Dorethy and Reeves (1979), Doerr (1980), and Springer & Deutch (1981). However, when the contribution of the various subscales that load onto the Nonverbal Divergent Thinking Factor were analyzed, it was found that scores in scales that assess Nonverbal Fluency and Flexibility were significantly higher in subject with a right ear advantage, whereas scores on the Nonverbal Figural Originality Subscale exhibited a significant opposite trend. Fluency and Flexibility may be associated with the 'Process' subdomain, whereas Originality, namely the ability to produce non-obvious yet appropriate ides is associated with the 'Product' subdomain. It is also clear from the results that a significant difference between scores obtained in the two subdomains was observed only in the group which had a clear left ear advantage. This group achieved lower scores in the scale associated with the 'Process' subdomain compared to its own scores in scales associated with the 'Product' subdomain. In other words, individuals with a clear left ear advantage generated a relatively small number of ideas when processing nonverbal stimuli. However, when the quality of their ideas is assessed and compared with that of people with a right ear advantage, it is found to be of equal or of slightly better quality, although the latter group excelled in the process subdomain. It produced a larger number of ideas and more diverse ideas.

A question is raised as to why the ear lateralization that was observed in the different subscales that constitute the Nonverbal Divergent Thinking Factor did not extend to the subscales that constitute Verbal Divergent Thinking Factor. An analysis of the assignments that constitute the Nonverbal Divergent Thinking Factor reveals that these tasks require primarily nonverbal abilities (drawing figures), while the assignments that constitute the Verbal Divergent Thinking Factor, require both verbal (responding by writing to questions) and nonverbal (looking at pictures and forming mental images) abilities. Thus, the need for both verbal and nonverbal skills in solving the different tasks influenced the subjects' performance and may have interfered with the emergence of lateralized ear advantage trends in the subscales that constitute the Verbal Divergent Factor.

Another question is raised as to whether the high quality of ideas that were generated by individuals with left ear advantage in the nonverbal subdomain extends to the verbal subdomain. The strong correlation of the Originality Index on EAI suggests that this is not the case. Individuals with a right ear advantage score better in the Verbal Originality Scale compared to their own scores in the Nonverbal Originality Scale and vice versa. Individuals with a left ear advantage excel in the nonverbal 'Product' subdomain compared to their scores in the verbal 'Product' subdomain.

The findings of the present research fit well with the proposition that creativity is a multi-faceted cognitive construct and that analysis of creative processes must distinguish between the various demands of creative thinking and creative task performance. These results are also consistent with the notion that creativity is a mode of thought in which seemingly unrelated ideas may be brought together in unique ways by both hemispheres of the brain (Torrance, 1982). Future studies, however, should employ Divergent Thinking tasks that are unequivocally verbal as opposed to nonverbal.

REFERENCES

ANASTASI, A. *Psychological Testing* (3rd ed.). NYC: MacMillan, 1968.

BARRON, F. & WELSH, G. Artistic perception as a possible factor in personality style: Its measurement by a figural preference test. *Journal of Psychology*, 1952, *33*, 199-203.

BELCHER, T. I., RUBOVITS, J. J. & DIMEO, P. A. Measurement of creativity: A factor analytic study. *Psychological Reports*, 1981, *48*, 819-825.

BRIGGS, G. & NEBES, R. Patterns of hand preference in a student population. *Cortex*, 1975, *5*, 230-238.

DELLAS, M. & GAIER, L. E. Identification of creativity: The individual. *Psychological Bulletin*, 1970, *73*(1), 55-73.

DORETHY, R. & REEVES, D. Mental functioning, perceptual differentiation, personality, and achievement among art and non-art majors. *Studies in the Art education*, 1979, *20*(2), 52-63.

DOERR, S. L. Conjugate lateral eye movement, cerebral dominance, and the figural creativity factors of Fluency, Flexibility, Originality and Elaboration, *Studies of the Arts Education*, 1980, *21*(1), 5-11.

EKSTROM, R., FRENCH, J., HARMAN, H. & DERMAN, D. Manual for Kit of Factor-Referenced Cognitive Tests. *Educational Testing Service*, Princeton, NJ, 1976.

GOWAN, J. C. The production of creativity through right hemisphere imagery. *Journal of Creative Behavior*, 1979, *13*(1), 39-51.

HARPAZ, I. Asymmetry of Cognitive Functioning As A Possible Predictor of Vocational Counselling and Personal Classification. *Journal of Vocational Behavior*, 1983, *23*, 305-317.

HELLIGE, J. Hemispheric x Task interaction and the study of laterality. In Hellige, J. (ed.), *Cerebral Hemispheric Asymmetry*, 1-17. NYC: Preger Publishers, 1983a.

HELLIGE, J. The study of cerebral hemispheric differences: Introduction and overview. In Hellige, J. (ed.), *Cerebral Hemispheric Asymmetry*, 1-17. NYC: Preger Publishers, 1983b.

HETTEMA, P. Cognitive abilities as process variables. *Journal of Personality and Social Psychology*, 1968, *10*, 461-471.

KATZ, A. N. Creativity and individual differences in asymmetrical cerebral hemispheric functioning. *Empirical Studies of Art*, 1983, *1*, 3-16.

KATZ, A. N. Creative styles: Relating tests of creativity to the work patterns of scientists. *Personality and Individual Differences*, 1984, *5*(3), 281-292.

KRASHEN, S. & HARTMAN. An unbiased procedure for comparing degree of lateralization of dichotically presented stimuli. *UCLA working papers in phonetics*, 1979, *24*, 63-70.

MARTINDALE, C. & HASENFUS, N. EEG differences as a function of creativity, stage of creative process, and effort to b original. *Biological Psychology*, 1978, *6*, 91-100.

MEDNICK, S. A. & MEDNICK, M. T. *Examiner's manual: Remote Association Test.* NYC: Houghton Mifflin, 1967.

NUNNALLY. *Psychometric Theory* (2nd edition). NYC: McGraw-Hill Book Company, 1978.

OHNMACHT, F., WEAVER, W. & KOHLER, E. Close and closure: A factorial study. *Journal of Psychology*, 1970, *74*, 205-217.

REKDAL, C. K. Hemispheric lateralization, cerebral dominance, conjugate saccadic behavior and their use in identifying the creatively gifted. *The Gifted Child Quarterly*, *XIII*, 1979(1), 101-168.

REPP, H. B. Stimulus Dominance and Ear Dominance in the Perception of Dichotic Voicing Contrasts. *Brain and Language*, 1977 *5*, 310-330.

SPRINGER, S. & DEUTSCH, G. *Left Brain, Right Brain.* W. H. Freeman & Company, San Francisco, CA, 1981.

TORRANCE, E. P. *Torrance Test of Creative Thinking* (Norms and technical manual). Lexington, MA: Personal Press, 1974.

TORRANCE, E. P. Hemisphericity and creative functioning. *Journal of Research and Development in Education*, 1982, *15*(3), 29-37.

TREFFINGER, D. J. Research on Creativity. *Gifted Child Quarterly*, 1986, *30*(1), 15-19.

UEMURA, A. K. *Individual differences in hemispheric lateralization.* Unpublished Ph.d. Dissertation. University of Maine, Orono, ME, 1980.

WELSH, G. Creativity and intelligence: A personality approach. *Institute for Research in Social Science,* University of North Carolina at Chapel Hill, 1975.

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