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Heart Rate Variability and Respiratory Concomitants of Visual and Nonvisual "Imagery" and Cognitive Style

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Attention to visual and nonvisual imagery, elicited by an imagery questionnaire, was studied using both within and between subjects analyses of cardiac and respiratory parameters. Visual imagery was accompanied by more regular interbeat heart rate (HR) and shorter, more stable respiratory cycles than nonvisual imagery. "Visually-oriented" thinkers (visualizers), identified by a word association test, manifested less overall variability in HR than "verbally-oriented" thinkers (verbalizers), as well as less variable HR and respiratory period during visual imagery. Visual and nonvisual imagery differed in HR variability for verbalizers and in respiration period for visualizers. The results are discussed in terms of the concepts of attention deployment, "mental load," cerebral asymmetry, and stylistic personality differences in cognitive functioning.

Advances in cognitive psychology, stimulated by the revival of the concept of imagery, have important implications for the study of personality. A strong case has been made for the existence of two qualitatively different information processing systems, viz., a visual imagery system specialized for parallel, multiple, or simultaneous processing and a verbal system organized for serial or sequential processing (Bower, 1970; Neisser, 1963; Paivio, 1971). Furthermore, experimental and clinical evidence suggests that these systems may be differentiated in the brain along hemispheric lines—verbal processing seems to be mediated more efficiently in most individuals by the left hemisphere, whereas visuospatial and other kinds of nonlinguistic processing are typically performed more efficiently by the right hemisphere (Bogen, 1969, pp. 101-125; Seamon, 1974, pp. 184-203; Studdert-Kennedy & Shankweiler, 1970). It has been argued, however, that this distinction is inadequate to encompass all of the existing data. Alternatively, it has been proposed that the left hemisphere in right-handed individuals is specialized for propositional, analytic, serial processing, whereas the right

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hemisphere is adapted for the organization of appositional, holistic, synthetic relationships (Bever & Chiarello, 1974; Bogen, 1969, pp. 101–125; Ornstein, 1972). Other evidence also suggests that individuals may have stylistic preferences for one or the other of these information processing modes (Bakan, 1971; Drewes, 1958; Richardson, 1969; Roe, 1951; Ornstein & Galin, Note 1).

In the search for physiological indices of imagery the cortex and the oculomotor system have been the most frequent targets for investigation Galin & Ornstein, 1972; Kinsbourne, 1972; Kocel, Galin, Ornstein, & Merrin, 1972; Morgan, MacDonald, & Hilgard, 1974; Richardson, 1969; Paivio, 1973, pp. 263–295; Zikmund, 1972, pp. 355–387). However, some evidence scattered throughout the psychophysiological literature suggests that it may be profitable to look at the autonomic nervous system for potential indicators of imagery. Gola and Antonovitch (1929) found two types of "habitual respiration," viz., a regular type associated with visual imagery and an irregular type associated with verbal imagery. Subsequently, Wittkower (1934) and Paterson (1935) both reported that psychotic patients breathed much more regularly than normal subjects. Wittkower speculated that the greater respiratory regularity of psychotics may have been associated with a predilection for visual thinking. Another more recent study (Chowdhury & Vernon, 1964) found a small, but significant, correlation ($r = 0.38$) between visual imagery scores on the Burt–Galton vividness of imagery questionnaire and respiratory regularity.

Other investigators have recorded respiration concurrently with the EEG (Gola, Hutton, & Grey Walter, 1943; Short, 1953). Both of these studies found that regular respiration was associated with a specific pattern of EEG alpha activity in subjects who characteristically reported using visual imagery during simple cognitive tasks, while irregular respiration was associated with a different pattern of alpha activity in subjects whose thinking was dominated by verbal imagery. Short (1953) found, in addition, that both types of subjects showed increased regularity in breathing when engaged in visual tasks.

Another autonomic parameter, the phasic heart rate (HR) response (a brief deceleration or acceleration), has become one of the most widely used psychophysiological measures for studying attention and other cognitive functions (Lacey & Lacey, 1970, pp. 205–227; Porges, 1972). In addition, HR variability, which seems to be relatively independent of HR level (Lacey, 1950; Porges, 1972), appears to be related to different aspects of attentional performance (Price, 1970; Porges, 1972). Specifically, there is evidence that HR variability may be taken as an index of *attentional motility*. Relative to a resting level, sustained attention to sensory inputs seems to be accompanied by reduced HR variability, while rapidly shifting attention during complex mental tasks is apparently associated with augmented HR variability (Spence & Lugo, 1973).

In any psychophysiological study of imagery, it is important to note that physiological changes accompanying imagery may reflect alterations in a number of processes that are not specific to imagery alone, viz., arousal, attention, emotionality, etc. (Zikmund, 1972, pp. 355–387); thus, physiological correlates of visual imagery should not be taken as exclusive, objective indicators of visual processing. There is the additional problem that the level of difficulty (information processing load) of "verbally-mediated" tasks may be different from that of "visually-mediated" tasks. Furthermore, Sokolov's (1972) work demonstrates the conceptual and practical difficulties involved in isolating a "purely visual" or a "purely verbal" process, i.e., "covert speech," as measured by electrical activity in the speech musculature, was rarely found to be absent even during the most highly visually-oriented tasks. For these reasons, terms such as *visual image, nonvisual image,* and the like should routinely carry the qualifying adjective *ostensive* or be enclosed in quotation marks. However, for economy of presentation in this paper, such qualifications will be construed as implicit in any terms pertaining to imaginal processes.

The present research, using the simple expedient of instructing subjects to generate and concentrate upon visual and nonvisual images, represents a preliminary, heuristic exploration of the usefulness of certain cardiac and respiratory parameters for the study of visual and nonvisual information processing. For the specific experimental context to be described below, it was presumed that visual imagery would be principally organized in the majority of individuals as a nonsequential, right-hemispheric process, whereas nonvisual imagery would tend to involve sequential, left-hemispheric mechanisms. Concentration on a single visual image, e.g., the image of a familiar person, is more apt to involve a single act of orientation than concentration on a kinesthetic image, such as remembering the feeling of running upstairs, or an auditory image, such as recalling the sound of hands clapping in applause; both of the latter seem to be temporally organized in a sequential series. If so, visual imagery should be associated with periods of sustained attention, whereas nonvisual imagery should require frequent attentional shifts; thus, visual imagery should be associated with lower HR variability than nonvisual imagery. Informal, exploratory research supported this hypothesis and further suggested that visual thinkers would tend generally to manifest lower HR variability than verbal thinkers during imagery in several sensory modalities.

The literature also suggested the hypotheses that visual imagery would be accompanied by less respiratory variability than nonvisual imagery and that visualizers would manifest less respiratory variability during visual imagery than verbalizers. Specific directional hypotheses pertaining to respiration frequency and amplitude concomitants of imagery were not formulated for investigation in this study, however, although it was planned to make appropriate supplementary analyses using these respiratory parameters.

METHOD

Subjects

Twenty-four male adults (18–24 yr) served as subjects. Volunteers were solicited by the experimenter from individuals present in the university locale during the summer when the university was not in session. All but three of the subjects were Wesleyan University students. No assessment of handedness was made.

Test Materials

Imagery test. A modified version of the Betts QMI Vividness of Imagery Scale (Richardson, 1969) was used to stimulate visual and nonvisual imagery. While the Betts scale requires subjects to form five images in each of seven modalities and to rate each image on a seven-point scale, auditory, kinesthetic, and "organic" modalities were chosen to represent nonvisual imagery in this study. "Organic" imagery consists of cognitive representations of prior experiences such as having a sore throat, feeling drowsy, etc. The test was scored by summing the vividness ratings separately for each imagery condition, for the nonvisual conditions, and for all conditions combined.

Word association test. Previous research (Moran, 1966; Stanford, 1967) has identified several "idiodynamic associative sets," construed to be relatively enduring personal characteristics that influence associational processes. One of these sets, the predication (perceptual referent) set, creates a disposition for forming noun-adjective or adjective-noun combinations in which the adjective denotes an attribute of the noun (i.e., *SPIDER–black* or *COLD–snow*). While predication responses may refer to nonvisual attributes of the noun, it has been noted that predication set subjects report more visual imagery intervening between stimulus and response than other subjects (Dunn, Bliss, & Siipola, 1958; Jung, 1919). Jung (1919) observed that attempts to distract a "predicate type" from his usual associative patterns were remarkably unsuccessful, and he explained this phenomenon in terms of the attentional demands of vivid visual imagery. Stanford (1967) also found that predication set subjects were the least successful of all types in assuming a nonpreferred response set.

It has been shown that time pressure generally increases the tendency for giving "popular" associations (Horton, Marlowe, & Crowne, 1963; Moran, 1966). Thus, nonpredicate-type subjects should give even fewer predication responses when under time pressure than when not; predicate types should be affected to a lesser degree. Accordingly, subjects were given 5 sec to respond to each of the 40 concrete nouns used by Stanford (1967) in studying idiodynamic sets. Thirty of these words tend strongly to elicit nonpredication responses, and only these were used to obtain the predication score; the entire list was given, however, since the word sequence was designed to balance order effects that might tend to favor a particular kind of response. High predication scores were taken to represent a tendency toward visual thinking, whereas low predication scores were taken to represent a predilection for verbal thinking.

Apparatus

Electrophysiological recordings of HR and respiration cycle were obtained by means of a Beckman R-411 Dynograph. Input from chest leads was fed into a Beckman cardiotachometer coupler (Type 9857), which converted successive R–R intervals in the EKG into a running histogram of interbeat HR. Respiration was recorded using a strain gauge fastened around the chest, which was connected to a Beckman multipurpose coupler (Type 9853A). Paper speed was 5 mm/sec. Task periods were marked manually with the Dynograph marker pen, and subjects' oral responses were tape-recorded.

Procedure

The volunteers were informed that the research involved a study of physiological changes during thinking. The experimenter remained blind regarding the hypotheses of the research until all data were collected and tabulated.

All instructions were tape-recorded. First, the subject was instructed to respond orally with his first association to each taped stimulus word. He was told that it was not unusual to fail occasionally to think of a response within 5 sec but that he should try to respond to all of the words. Next, he was instructed to generate each image described in the modified Betts scale, concentrate on it for 15 sec, and give an oral rating of the vividness of the image on the seven-point rating scale provided. Then, the imagery items, counterbalanced by modality, were read orally by the experimenter, i.e., each subject responded to the items in a different arrangement such that every modality occurred equally frequently in the temporal order and was followed an equal number of times by each of the other modalities.

Tape recordings of subjects' responses were transcribed by the experimenter. Predication responses were scored by the author, who was blind as to the physiological data and imagery ratings, using a scoring guide that has been shown to facilitate high interscorer reliability. In an unpublished study the author's scoring of subject predication score correlated quite reliably with the independent scoring of another judge ($r = 0.94$, $n = 49$).

Physiological Measures

Heart rate variability. The cardiotachogram was routinely calibrated to indicate a change of 2 bpm (beats per minute) for every 1 mm of pen deflection. The maximum range of interbeat HR (in bpm) per 5-sec interval was measured (HR_V). Detailed instructions for scoring have been provided elsewhere (Price, 1970). Blind scoring was performed by an undergraduate assistant. Median HR_v was used to index HR variability and is represented by the notation $HR_v(Q_2)$.

Heart rate level. To provide supplementary information on the relationship between HR_v and HR level, each interbeat HR (in bpm) was scored by the author after analyses of all other data had been completed for more than 1 yr. This scoring was "quasi-blind" in the sense that the author could only connect subject numbers and predication scores with subject names in a small number of cases and could recall that subjects numbered 1–6 received the visual imagery condition first. Thus, most identifying information was not consciously known during this scoring. Median interbeat HR was used to index HR level and is denoted by $HR(Q_2)$.

Respiration period. The shortest respiratory cycle (peak–peak or trough–trough interval) for each of the 5-sec intervals used in scoring HR_v was measured to the nearest one-tenth of a second (R_p). If a cycle was not completed within the interval under consideration, then the interval was extended by 1 sec on either side as needed. Thus, the largest possible score was 7 sec; cycles longer than this were scored *L* for long cycle. Data were scored blind by the HR_V scorer. Median R_p was used to index respiration period and is symbolized by $R\ (Q_2)$.

Respiration variability. The interquartile range of R_p scores, represented by $R_p(Q_{3-1})$, was computed by the author, who was not blind as to the conditions or the predication scores.

Respiration amplitude. The largest peak–trough change in respiration for each 5-sec interval used in scoring HR_v was measured to the nearest .5 mm (R_a). Blind scoring was performed by another undergraduate assistant. Median R_a was used to index respiration amplitude and is symbolized by $R_a(Q_2)$.

RESULTS

Autonomic Differentiation of Imagery Modality

A Friedman Analysis of Variance (ANOVA) for ranked data was performed for each of the physiological parameters. As shown in Table 1, the imagery instructions produced significant differences across conditions in HR variability, respiration period, and respiration variability but not in HR level or respiration amplitude.[1]

Median HR_v scores for the nonvisual modalities were averaged for each subject and contrasted with his median HR_v score in the visual condition by means of the Wilcoxon Signed-Ranks Test. Visual imagery was associated with significantly lower HR variability than nonvisual imagery [$T(24) = 30$, $p \leqslant .005$, one-tailed], as predicted. By a similar procedure it was demonstrated that visual imagery was also associated with significantly shorter respiration cycles [$T(22) = 33$, $p \leqslant .01$] and lower respiration variability [$T(19) = 45.5$, $p < .05$] than nonvisual imagery. Two subjects were omitted from the respiration analyses because of gross artifacts in the recordings; three additional subjects were dropped from the respiration variability analysis because the number of *L* cycles precluded a determination of the interquartile range.

Autonomic Differentiation of Cognitive Style

While the research design called for a median split of predication scores to form visualizer and verbalizer groups, the distribution of predication scores did not lend itself in simple fashion to this procedure. The distribution was skewed, and the range was extremely curtailed; the modal predication score was zero ($n = 8$), while there were seven scores of 1 and seven scores ranging from 2 to 5 (median = 0.93). Two subjects were omitted because of inadvertent erasure of their word association tapes.

Thus, it was decided to depart from the original plan and segregate the predication scores of 1 (comprising 32% of the sample) in identifying the visualizer and verbalizer groups. This decision was made without any knowledge of the physiological or imagery vividness data. Accordingly, *visualizers* were defined as subjects giving two or more predication

[1] Within-conditions (across-subjects) measures of central tendency and dispersion derived from the raw data are also presented in Table 1, although these were not used in the nonparametric, within-subjects analyses of differences among the imagery conditions. These supplementary tabulations provide rough indications of the general level of autonomic activity during imagery but are not appropriately used in comparing conditions.

TABLE 1
CARDIAC AND RESPIRATORY CONCOMITANTS OF IMAGERY MODALITY

Parameter	Imagery			
	Visual	Auditory	Kinesthetic	Organic
$HR(Q_2)$[a]				
Grand median	76.83	79.20	77.83	78.50
Grand interquartile range	20.42	22.98	19.77	23.40
Friedman Σ ranks	62.0	52.5	61.5	64.0
$HR_v(Q_2)$[b]				
Grand median	7.10	8.68	9.00	10.00
Grand interquartile range	3.82	3.76	6.42	7.19
Friedman Σ ranks	40.0	54.0	65.5	80.5
$R_p(Q_2)$[c]				
Grand median	3.38	3.53	3.48	3.59
Grand interquartile range	.59	.96	.74	.96
Friedman Σ ranks	42.0	58.5	48.5	71.0
$R_p(Q_{3-1})$[d]				
Grand median	.41	.51	.62	.72
Grand interquartile range	.35	.67	.69	1.43
Friedman Σ ranks	40.0	40.0	47.0	63.0
$R_a(Q_2)$[e]				
Grand median	—	—	—	—
Grand interquartile range	—	—	—	—
Friedman Σ ranks	60.0	59.5	62.5	58.0

[a] Median interbeat HR level (bpm); HR calibration sheets missing for five subjects; thus, $n = 19$ for grand medians and interquartile ranges. χ^2_{ranks} (3) = 1.96, NS; since Friedman ANOVA is a within-subjects analysis, HR calibration is unessential and $n = 24$.

[b] Median HR variability (maximum interbeat HR range in bpm/5 sec); standard laboratory procedure required that HR change be calibrated at 2 bpm/mm irrespective of the calibration of HR level; thus, $n = 24$. χ^2_{ranks} (3) = 22.54, $p \ll .001$.

[c] Median R_p (shortest respiratory cycle measured in seconds/5 sec); records of two subjects unscorable because of artifacts in recording; thus, $n = 22$. χ^2_{ranks} (3) = 13.26, $p < .005$.

[d] Interquartile range of R_p scores (sec); records of three additional subjects unscorable because of large number of cycles longer than 5 ± 1 sec; thus, $n = 19$. χ^2_{ranks} (3) = 11.06, $p = .01$.

[e] Median respiration amplitude (largest peak–trough or trough–peak change measured in .5 mm/5 sec); method of recording respiration did not permit reliable across-subjects determination of amplitude measure. χ^2_{ranks} (3) = .27, NS.

responses, while *verbalizers* were identified as subjects giving only non-predication responses. While this difference was not large, it was sufficient for revealing physiological differences between the groups. In this connection, it is pertinent to note also that the scoring guide for predication responses employs very stringent criteria. For example, the stimulus–response combination *LAKE–placid* is not scored since it may have been a reference to Lake Placid, New York, presumably a verbal association. Similarly, the combination DOORS–open is not scored since there is ambiguity as to whether "open" was intended as a verb or as an adjective.

As noted above, predication responses need not refer only to visual attributes of nouns. However, in this study 85% (22/26) of the predication associations were visual in nature. The four nonvisual responses, all given by subjects in the visualizer group, were tactual referents.

To test the hypotheses pertaining to cognitive style, the following analyses were performed. Median HR_v was computed across all imagery conditions for each subject. The Mann–Whitney U test was computed for these data, and it confirmed that visualizers manifested significantly lower HR variability than verbalizers during the imagery conditions as a whole [U (7, 8) = 8, $p = .01$, one-tailed], as hypothesized. Similar comparisons were also made for overall median HR and overall median R_p, revealing that neither the difference between the groups in heart rate level [U (6, 6) = 11, $p > .20$] nor the difference in length of the respiratory cycle [U (7, 7) = 18, $p > .20$] was significant. Between subjects, comparisons of respiration amplitude were precluded by the method of measurement. When the groups were compared in terms of the $R_p(Q_{3-1})$ measure for the visual imagery condition, visualizers were found to show significantly lower variability in respiration period than verbalizers [U (6, 7) = 8, $p < .04$, one-tailed], as hypothesized; a similar comparison for median HR_v yielded a parallel result [U (7, 8) = 9, $p = .01$, one tailed].[2]

Table 2 provides a summary of the physiological data by cognitive style category. Comparison data for the seven subjects (intermediates) not included in the visualizer–verbalizer groups are also presented. Supplementary Kruskal–Wallis ANOVA's revealed a significant difference between groups for $HR_v(Q_2)$ only [χ^2 (2) = 8.20, $p < .02$]. All other comparisons resulted in a χ^2 (2) $\geqslant$ 4.20, $p \geqslant .13$, this limit obtaining in the case of $R_p(Q_{3-1})$. The intermediates, like the visualizers, were significantly lower in HR variability than the verbalizers [U (7, 8) = 6, $p = .01$]; visualizers and intermediates did not, however, differ significantly from one another [U (7, 7) = 24, $p > .20$] in terms of this cardiac parameter.

Stylistic Differences in the Autonomic Correlates of Imagery Modality

Friedman ANOVA's were computed separately for the visualizer, verbalizer, and intermediate groups. Visualizers manifested a significant

[2] See footnotes to Table 1 for an explanation of the discrepancies in group size for the different comparisons. The five subjects omitted from the between-groups analyses of HR level included two verbalizers and one visualizer.

TABLE 2
COGNITIVE STYLE CATEGORIES AND CARDIAC AND RESPIRATORY ACTIVITY DURING IMAGERY

Autonomic parameter	Verbalizers	Intermediates	Visualizers
$HR(Q_2)$[a]			
Grand median	84.33	74.97	74.37
Grand interquartile range	22.50	20.36	28.59
$HR_v(Q_2)$[b]			
Grand median	11.46	7.18	7.39
Grand interquartile range	9.04	3.84	6.17
$R_p(Q_2)$[c]			
Grand median	3.63	3.34	3.15
Grand interquartile range	.74	.74	1.22
$R_p(Q_{3-1})$[d]			
Grand median	.62	.42	.32
Grand interquartile range	1.02	1.72	.47

Note. Two subjects were omitted because of inadvertent erasure of word association tapes, leaving base samples of eight verbalizers, seven intermediates, and seven visualizers, subject to the contingencies noted specifically below. Data are tabulated for the imagery conditions as a whole except in the case of $R_p(Q_{3-1})$, where the data are presented for the visual condition separately because of the specific nature of the hypothesis tested.

[a] Median interbeat HR level (bpm); HR calibration sheets missing for five subjects, one of whom was omitted previously because of missing word association data; thus, $n = 6$ for all groups.

[b] Median HR variability (maximum interbeat HR range in bpm/5 sec).

[c] Median R_p (shortest respiratory cycle measured in seconds/5 sec); data for two verbalizers omitted because of artifacts in recording of respiration.

[d] Median interquartile range of R_p (sec); data for two verbalizers omitted because of artifacts in recording of respiration. Long cycles did not preclude computation for any subjects in the visual imagery condition.

difference only in respiration period between imagery conditions [χ^2_{ranks} (3) = 11.35, $p < .01$]; verbalizers showed a significant effect for HR variability [χ^2_{ranks} (3) = 7.96, $p < .05$] and a near significant effect for respiration variability [χ^2_{ranks} (3) = 7.50, $p < .06$], while intermediates were similar to the latter in evincing a significant effect for HR variability [χ^2_{ranks} (3) = 14.42, $p < .007$] and a near significant effect for respiration variability [χ^2_{ranks} (3) = 7.00, $p < .08$]. The Wilcoxon Test revealed that visual imagery was associated with shorter respiration cycles than nonvisual imagery for visualizers [T (7) = 0, $p = .02$] and lower HR variability than nonvisual imagery for verbalizers [T (8) = 0, $p = .01$] and also for intermediates [T (7) = 1, $p < .05$].

These results are in contrast to previous comparisons of the groups, which revealed that, in terms of overall physiological measures, intermediates were somewhat more similar to visualizers, particularly with respect to HR variability. This is not especially surprising, however, since the intermediates might be expected to show some similarities to each of the other groups. However, it is important to note that the counterbalancing for any order effects of the imagery conditions breaks down when the Friedman ANOVA's and other comparisons of imagery conditions are made separately by cognitive style group.

Vividness of Imagery, Imagery Modality, and Cognitive Style

The four imagery modalities did not differ significantly in mean vividness ratings as assessed by the Friedman ANOVA [χ_r^2 (3) = 2.45, $p > .20$]. In addition, the differences between conditions were not significant for any of the three groups taken separately. Furthermore, it was found that the groups reported extraordinarily similar ratings indicating clear and vivid visual, as well as nonvisual, imagery.

Relationships between Cardiac and Respiratory Measures

Intercorrelations between the $HR_v(Q_2)$, $HR(Q_2)$,$R_p(Q_2)$, and $R_p(Q_{3-1})$ measures were computed. The $R_a(Q_2)$ measure was not included for reasons already specified. None of the obtained Pearson correlations reached significance at the .05 level. Of special interest is the correlation between $HR_v(Q_2)$ and $HR(Q_2)$, which was only .17.

DISCUSSION

Some general comments regarding the experimental differentation of imagery modalities and visualizer and verbalizer styles are necessary for providing the proper context for discussing the present findings. First, the distinction between imagery conditions was operationally anchored only in a difference in antecedent instructions, which produced no observable nonphysiological consequences. Second, the similarity of the vividness of visual imagery ratings for the stylistic groups raises immediate questions as to the nature of the distinction between the groups. Is the word association test a more reliable and sensitive technique for assessing visualizing tendency than the Betts rating procedure, or is the former tapping a difference that has nothing to do with preference for a visual or a verbal processing style? The finding that "visualizers" manifested more regular respiration during visual imagery than "verbalizers" is consistent, however, with previous research that used different methods for differentiating visual and verbal thinkers, and thus it provides some validation of the predication response measure.

The physiological data clearly suggest that the cognitive responses to instructions to image visually and nonvisually are different and that subjects with "visually oriented" associative processes manifest greater cardiac and respiratory rate stability during visual imagery than "verbally oriented" subjects. At least three explanations for these results may be offered: (1) There are two cognitive modes that are differentially involved in the processing of visual and nonvisual imagery; each mode is presumably mediated by a different hemisphere of the brain, the functions of which have different cardiac and respiratory correlates. (2) Visual and nonvisual imagery tasks differ significantly in difficulty (information load). (3) Visual and nonvisual imagery tasks impose differential demands for attentional motility. These are not, however, mutually exclusive explanations. For example, multiple, parallel, holistic processing of a visual pattern in the right hemisphere might impose greater information load than sequential, analytic processing of nonvisual information in the left hemisphere.

Since no relationships between EEG measures of cerebral laterality or asymmetry and autonomic parameters have been established, the present data taken alone can provide only prima facie evidence for Alternative 1. More, however, will be said below in connection with Alternative 3.

It may be noted, in conjunction with Alternative 2 that European investigators have used HR variability as an index of "mental load," operationalized as the number of binary choices per minute. A substantial number of studies have found that mental load is negatively related to HR variability (Blitz, Hoogstraten, & Mulder, 1970). If visual processing imposes greater mental (information) load than nonvisual processing, then this fact could account for lower HR variability during visual than nonvisual imagery. Furthermore, if visualizers tended to utilize holistic or visual processing, as well as sequential processing, in the nonvisual conditions, then this could account for their generally lower level of HR variability.

There are, however, some difficulties with the "mental load" interpretation. Blitz et al. (1970) found in their own research that one of their "rest conditions" (tapping a ballpoint pen in time with a metronome) produced even lower HR variability than their high load binary choice condition, and another rest condition (light reading) was associated with HR variability comparable to their moderate load condition. In addition, Danev, Wartna, Bink, Radder, and Luteyn (1971) found that mental load, operationalized as the number of potential choices in a reaction task, was related to two of eight measures of HR variability but in the direction opposite to that of the binary choice situation.

The heuristic for the present study of HR variability and imagery emerged from a synthesis of Alternatives 1 and 3. It was hypothesized that visual imagery would be more apt to involve nonsequential, right-hemispheric processing than nonvisual imagery, while the latter would be the more likely to involve sequential, left hemispheric functioning; sequential processing would seem to require rapid shifts in focused attention, while nonsequential processing might be expected to require sustained, albeit perhaps broadly deployed, attention.

The auditory and kinesthetic items of the Betts QMI may be effectively organized in a temporal series, which would produce greater attentional shifting, and thus, inferentially, concomitantly greater HR variability, than the visual items. This does not seem to be true, however, for the organic items, which showed the highest level of HR variability in this study. In the latter case it is hypothesized that attempting to recreate feelings of hunger, having a sore throat, fatigue, etc., may trigger a variety of verbal, sequential associations, some of which may divert attention from negative, or otherwise affectively charged, experiences of a very personal nature. Singer, Greenberg, and Antrobus (1971) have reported that ocular motility increased substantially, relative to a base line period, when subjects attempted to suppress a thought, while Antrobus (1973, pp. 355–368) has reported covariation between ocular motility and HR variability in a signal detection task.

It is possible that verbalizers tended to show generally higher HR variability than visualizers because of a greater predilection for generating verbal associations during imagery periods. While retrieving and attending to a visual image, the verbalizer may be more disposed than the visualizer to talk subvocally to himself, shifting his attention repetitively between the image and his verbal associations. In rating the vividness of a visual image, the verbalizer, thus, may tend to be influenced by his verbal elaboration of the image. The fact that visualizers did not show a significant difference in HR variability between imagery conditions may reflect a tendency to experience visual imagery in the nonvisual conditions or generally to process information in a more holistic–relational manner. The contribution of verbal processing to the intergroup and intermodality differences in this study could be determined by using Sokolov's electromyographic methodology for detecting the presence of covert speech.

The hypothesis that individuals tend to manifest a tendency toward either a holistic–relational or an analytic–sequential processing style is supported by the research of Drewes (1958) and Roe (1951). In classifying college students into visualizer or nonvisualizer categories on the basis of EEG alpha activity, Drewes found that the former showed significantly more Rorschach responses than the latter, in which the blots were seen as whole, integrated patterns (*W* responses). Similarly, in categorizing research scientists into visual and verbal thinking groups on the basis of interview data, Roe found significantly more *W* responses in the protocols of the visual thinkers. The *W* response is said to reflect goal-directed striving toward global comprehension, a tendency to combine details into a meaningful whole, marked availability of visual memory images, as well as richness of associations (Kuhn, 1960, pp. 319–340).

Recent research on attentional styles (Silverman, 1968; 1970, pp. 61–98) has identified "field differentiation" as an important dimension of attention. Individuals may be characterized according to the extent to which they vary along a "continuum" of "segmentalizing-analytic" attention on the one extreme to "global-relational" attention on the other. This study's finding that visualizers manifested greater cardiac and respiratory quiescence during visual imagery is consistent with the hypothesis that visualizers tend to show sustained, globally deployed attention when instructed to concentrate on a visual image, while verbalizers tend to manifest focused, segmental, sequentially shifting attention. Other evidence also suggests that sustained, global attention may be associated with even more general physiological quiescence or stability. Singer et al. (1971) found, for example, that attending to static visual imagery was associated with significantly less ocular motility than seeking many solutions to an ordinary problem.

The results of this research clearly demonstrate that cardiac and respiratory parameters, particularly HR variability, provide promising dependent measures for studies of imagery, visual–verbal processing, and attentional or cognitive styles. The interpretation of these data, while highly speculative and dependent upon a number of inferential leaps, however, does suggest a rudimentary, heuristic model of cerebral asymmetry in attention deployment and its concomitant effects upon HR variability. Reciprocal, asymmetric influences of HR variability upon cortical functioning is also a possibility that could be explored in connection with the Lacey hypothesis of a cardiovascular feedback system that influences cortical excitability (Lacey & Lacey, 1970, pp. 205–227).

It also seems clear from the pattern of the data that HR variability is a viable parameter in its own right. Variations in interbeat HR may not be construed as merely secondary effects of HR level or of respiratory activity. This conclusion is consistent with the findings of other researchers (Hnatiow & Lang, 1965; Lacey, 1950; Lang, Sroufe, & Hastings, 1967; Porges, 1972).

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