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# Colors, Arousal, Functionalism, and Individual Differences

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**Abstract**: Some philosophers have regarded the connection between hues and certain arousal or affective qualities as so intimate as to make them inseparable, and this "necessary concomitance view" has been invoked to defend functionalism against arguments based on inverted spectra. Support for the necessary concomitance view has sometimes been thought to accrue from experiments in psychology. This paper examines three experiments, two of which apparently offer support for the view. It argues that careful consideration of these experiments undermines this appearance of support. General lessons are drawn concerning (a) the problem that individual differences present for functionalism, and (b) the difficulty of supporting strong conclusions about concomitance by using the methods of experimental psychology.

## 1. Introduction

Discussions of the possibility of inverted spectra often have a moment at which qualia from one sense—usually colors—are claimed to be necessarily connected with qualities from which they are at least verbally distinct. To take a leading example, C. L. Hardin wonders rhetorically "exactly how could phenomenal green be experienced as positive and warm and yet be green? If there is a 'residue' of green which is separable from its polarity, that residue would seem to correspond to nothing in experience or imagination . . . " (Hardin, 1988, p. 138). Admission of such a tight connection between apparently verbally distinguishable aspects of our experience may not be decisive against all criticisms of functionalism (see Levine, 1991). It does, however, make life more difficult for qualia theorists and proponents of inverted spectrum arguments, as is brought out not only in Hardin (1988), but also in Hardin's (1991) reply to Levine.

Let us call the view suggested by the quotation from Hardin the *necessary concomitant* view.[1] A contrasting theory would be the *contingent concomitant* view. According to this latter view, it may well be that, as a matter of contingent fact, color experiences are generally associated with properties that can be identified by words that would not ordinarily be counted as color words. This concomitance is, however, contingent, i.e., it would be possible to have an experience of a particular hue *without* also having an experience of the property that usually accompanies an experience of that hue.

This paper examines three works in experimental psychology to see how they may bear upon the debate between a necessary concomitant view and a contingent concomitant view. The experimenters who authored these works were not philosophers and were not directly addressing the views I have distinguished. Two of the items to be reviewed here have been selected because a brief statement of their results may suggest that they offer support for a necessary concomitant view. For example, G. D. Wilson offers the summary statement that "Results support the hypothesis that red is a more 'arousing' color than green, the effect being particularly apparent in the GSR [galvanic skin response] data" (Wilson, 1966, abstract). The main conclusion of the present paper, however, will be that when we look into these experiments more closely, we can see that in fact they offer no support for the necessary concomitant view. Our discussion will lead to a broader question about how we may conceive of the function that is to be associated with a particular color. Pursuit of this broader question will help to clarify the relation between functionalism, individual differences, and qualia realism.

It should be noted that empirical evidence is not appropriately adduced in support of a claim that colors are *necessarily* arousing, or *necessarily* possessed of some particular affective property. Despite this fact, some philosophers do speak as if very strong claims of "internal" connection between hue and arousal, or affect, are buttressed by empirical results. The nature of the connection can be obscured by formulating the

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[1] From discussion during the presentation of some of the material of this paper at the 2001 ASSC5 conference, I conclude that "necessary concomitance" overstates Hardin's actual view of the strength of the connection. I retain the term not only for its convenience, but because it remains appropriate for the way in which the connection between, e.g., color and arousal has been used in the dialectic surrounding functionalism and inverted spectrum arguments.

connection in functionalist terms, e.g., by claiming that arousal or affect is part of the functional specification of colors. For these reasons, an advance in our understanding can be expected if we clarify the nature of putative empirical evidence, and investigate what kinds of claims about hue and arousal or affect it may legitimately be taken to support.

Hardin's predicate, "warm" occurs explicitly in only one of the studies reviewed here. However, Hardin (1988, p. 130) adopts the convention of letting his "warm"/ "cool" division stand for an analogical polarity that has many expressions, explicitly including effects on "vital signs" such as pulse rate and blood pressure. Thus, the use of these and other physiological measures in the studies under review makes them relevant to necessary concomitant claims like the one quoted in our first paragraph.

## 2. A Suggestion of Contingency

I begin with a study that suggests an *absence* of connection between hue and several physiological measures. Mikellides (1990) placed 24 subjects in a 3.5m x 4.5m room in which walls, floor, ceiling and fittings were painted half in red (NCS 1674-Y9OR) and half in blue (NCS 1859 BO4G). Subjects were monitored for 20 minutes in each of four positions, in which their visual fields were (a) completely red, (b) completely blue, (c) left half red, right half blue, or (d) left half blue, right half red. EEG recordings were taken from four cranial positions: central right and left, and parietal right and left. Pulse rate and GSR were also recorded.

"The most important result of this study was, paradoxically, that there were no statistically significant differences in the experience of a red and blue space at the central nervous system [i.e., in the EEG recordings]" (p. 17). Likewise, while Mikellides reports more individual variation in the autonomic measures (pulse rate, GSR) than in the EEG recordings, the autonomic measures "produced almost identical mean scores for the two conditions" (i.e., presumably, the all red and all blue conditions – see Mikellides, 1990, p. 18).

Mikellides concludes that his results support the findings of Sivik (1970) and Kuller (1976) to the effect that it is not hue, but rather chromatic strength (saturation) that affects how exciting or calming a color is perceived to be (Mikellides, 1990, p. 15 and p. 19).

Mikellides points out that his study involves color in the form of pigment rather than colored light, as is used in some other studies (including the ones we shall shortly examine). It is also not clear exactly how GSR records were analyzed, and this is a potential source of noncomparability with results of other studies (see below). Although red is a color used in the next study we will discuss, blue was not. All these points suggest caution in comparing Mikellides' results with results of other studies. But none of these issues about comparability with other studies provide any reason for ignoring Mikellides' results. Functionalists who may be inclined to incorporate arousal as a part of the function that is performed by red experiences should at least complicate their view to allow that, e.g., arousal under certain conditions (e.g., color as light) is a function of red experiences, while arousal under other conditions (those in Mikellides' experiment) is not. (Strictly: they should either allow such a complication into the specification of the relevant function, *or* claim that it is not really the same color red that can be experienced through exposure to emitted light and exposure to reflected light. In suggesting the simpler formulation, I am taking it that the second disjunct here is implausible.)

## 3.Wilson’s Experiment

Wilson (1966) measured GSR of 20 subjects who viewed alternating highly saturated red and green slides projected on a translucent screen. Each slide was projected for one minute, then replaced without break by the other until 10 exposures (5 of each color) had been viewed. Half the subjects began the series with red, the other half with green.

Conductance level and GSR were recorded at 12 second intervals. The conductance measure for each trial for each subject was the mean of the 5 readings during an exposure, beginning at 12 sec. after onset. These means were converted to within-subject rankings, which were then averaged over the 20 subjects. The GSR measure was “the maximum increase in conductance, from the level at the time of stimulus onset, occurring within the first 12-sec. period.” This measure was likewise converted to a within-subject ranking and the rankings averaged over subjects. Subjective reports about the colors were also taken.

Wilson reports that “Results generally support the hypothesis that red induces higher arousal levels than green. The effect on absolute conductance level was small, but there was a clear difference in rapid conductance changes (GSRs) to the onset of the stimuli. Subjective reports were consistent with the electrodermal evidence; the red was variously described as more stimulating, exciting, awakening, attention-drawing, overpowering, and lively.”

The “clear difference” in GSRs referred to in Wilson’s conclusion is not given numerically, but, as noted, by averaged rank. Rank 1 for a single subject would be the largest change in conductance at the 12 sec. measure after one of the ten onsets for that subject; rank 2 for that subject would be the second largest change for that subject; and so on. A given trial number for a given color will have a particular rank for each subject. The GSR graph in Fig. 1 is obtained by taking the mean of the rank numbers that occurred for a given trial number and color across subjects. Thus, for example, when the reaction to the second exposure to green is reported as slightly less than 6, that would mean that, on average, second exposures to green were almost the sixth largest effect exhibited by subjects, out of the ten effects for each subject.

The main result of Wilson’s experiment is that there is a significant difference ($p< .002$) in rank of the change in conductance after onset of a red slide as compared with the change in conductance after onset of a green slide.

Although Wilson’s report is technically correct, its interest becomes less and less the more we examine the data. We may begin with the matter of the subjective reports, which I will argue must be set aside as too incomplete and possibly confounded to support any conclusion. We will then turn to the physiological measures.

Wilson did not report how he elicited subjects’ descriptions of the colors. He allows that “the red and green stimuli used in this experiment may possibly have differed on variables other than hue, but the most striking difference between them was certainly that of hue.” He states that subjects were asked which color was “lighter” and reports that 18 of the 20 said “green”. He explains that “lighter” was used in preference to “brighter” because the latter is often confused with saturation. He does not identify the stimuli other than describing them as “upright rectangles of highly saturated color” and, of course, red and green.

From the reported information, it is not possible to tell whether the relative "lightness" of the green was or was not a difference in perceived saturation. In the light of Mikellides' results, we must certainly suspect that such a difference could have made a crucial contribution to Wilson's results. Wilson may have intended "lighter" to elicit a response concerning brightness, but he reports no verification that this is the way it was taken by subjects. Regarding the list of adjectives used in subjects' descriptions, there is no information reported that would enable us to rule out the possibility that subjects were tapping into commonly held, but unverified, opinions about the relative salience of red and green, as opposed to making judgments solely about the experimental samples. Nor should we base anything on the idea that acceptance of common opinions by itself shows that red is more exciting than green. For one thing, this is the very proposition that the experiment was supposed to test. More directly, it may be that typical samples that one thinks of if asked to think of red (e.g., stop signs) are apt to be brighter or more saturated than typical samples brought to mind by "green" (e.g., lawns in summer). On the basis of these considerations, we should simply set aside the subjective reports as raising too many questions to count as evidence one way or another about the relative effect of red or green hue on arousal. Biases that subjects may have brought to the elicited descriptions from outside the experimental context are a possible confound that we can neither rule out, nor estimate the magnitude of.

Let us turn to the physiological measures. Here we need to comment on two points: Overall Decrease, and Individual Differences. Let us take these in turn.[2]

[2] A third point that stands out is the order effect, for which Wilson offers no explanation. It seems possible that red is more alerting after a green presentation than after the pre-slide darkness, and even that this effect "sensitizes" for red, so that responses to subsequent onsets of red are enhanced (i.e., after an initial relatively large response after green). This suggestion is, of course, entirely speculative; Wilson's report is too summary to confirm or refute it. The main point here, however, is that neither this explanation nor any other I can think of offers support for the necessary concomitant hypothesis, once attention is paid to individual differences, which are discussed in the main text. For, evidently (from Table 1) the enhancement of the hue effect due to beginning with green was absent or reversed in 18 of the 50 relevant subject-trials.

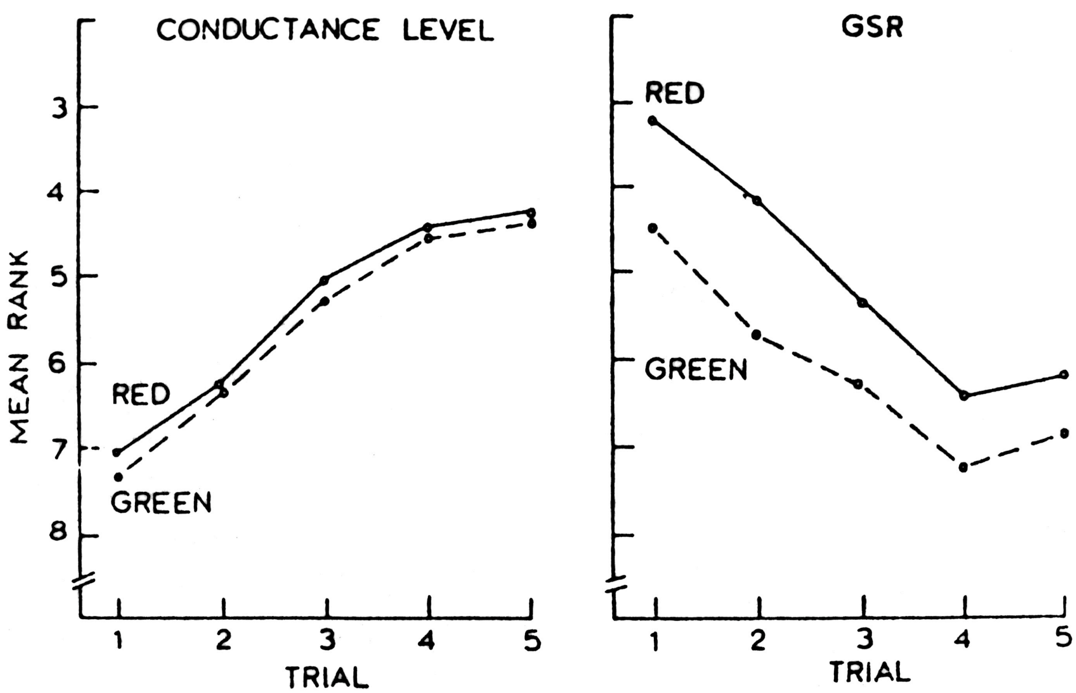


**Figure 1**: Mean within-subject ranks of conductance level and GSR (conductance change) scores compared for red and green stimuli. (Reproduced from Wilson (1966), p. 948.)

The right hand panel of Fig. 1 shows decrease of GSR with succeeding changes (except for the fourth and fifth exposures of each color). The left-most points represent the mean ranks of changes after the first onset of each color, which are averages of the ranks of changes from blank screen to first exposure of that color (i.e., when that color was first in order) and changes from the other color to the identified color (when the latter was second in order of presentation). We may note that in later trials, the mean rank of the change in arousal for red, while higher than the mean rank of the change in arousal for green on the same trial number, is lower than the mean rank of the change in arousal for green in earlier trials.

This fact of decrease is not in conflict with the conclusions of Wilson's experiment.[3] He has clearly detected some effect, which is visible in the continuing separation of the curves for red and green in later trials. However, the existence of this effect does *not* support the philosophical proposition that high change in arousal is a necessary concomitant of the onset of a red visual experience. In fact, the evidence *disproves* this proposition, because the ranking information entails that the change in arousal was less for some cases of red onset than it was for some cases of green onset. (We cannot dismiss the importance of this fact by saying that later responses to red would have been greater but for a ceiling effect, because the graph for conductance does not show such an effect taking hold until after the third trial; whereas GSR on first green

[3] The decrease might be viewed as habituation, or as a ceiling effect. This difference makes no difference to the argument that follows.

trials is of lower rank than GSR on third red trials.)

Now, strictly speaking, the conclusion that the necessary concomitant view is undercut by Wilson's results runs a little ahead of our argument. For there is a claim that could be made, that would rescue the necessary concomitant view. This claim is that the way the red looks is different on later trials than on earlier trials. If the visual experience of red habituates—if the red that subjects see is different on later trials, as compared with earlier trials—then one could hold that high arousal is a necessary concomitant of certain red experiences, and that it is no surprise that experience and arousal decrease together.

There is, however, no reason to believe this rescuing proposition, and every reason to doubt it. (a) To argue that the red experience *must* change if the change in arousal diminishes would be simply to beg the question. (b) No subject was reported as noticing a change in the colors on successive presentations. (c) Common observation tells us that color perception does not habituate; that is, one cannot get the hue experienced when looking at an object to change just by looking at it longer, or by repeatedly looking back and forth between it and some contrasting object.[4]

A deep skeptic could, of course, say that colors do habituate, but we just do not notice that that is happening. Perhaps, as scientists, we should refuse to dismiss this skepticism without experimental evidence; that is, perhaps we should dismiss common experience as merely anecdotal. Now, I am willing to base my thinking on a view that accords more weight than this to common experience. But let us note that if we adopt the stringently skeptical view, we do not get any support for the necessary concomitant view. What we get instead is agnosticism. We would have to regard ourselves as unable to know, absent further, as yet to be formulated experiment, whether arousal change diminished while hue experience remained constant, or whether both changed together. Or, to put the point in functionalist terms, we would have to say that we do not know how to specify the function that a candidate for a red experience would have to satisfy in order to meet the requirements of performing the function of red experiences.

Let us now turn to a discussion of individual differences. Table 1 shows that there were 44 (out of 100) cases where, on the same trial number, GSR for red failed to exceed GSR for green.

| | | R > G | R = G | R < G | p |
|---|---|---|---|---|---|
| Conductance level | R first | 14 | 4 | 32 | <.01 |
| | G first | 36 | 6 | 8 | <.0001 |
| | Total | 50 | 10 | 40 | ns |
| GSR | R first | 24 | 8 | 18 | ns |
| | G first | 32 | 8 | 10 | <.001 |
| | Total | 56 | 16 | 28 | <.002 |

**Table 1**. Summary of Sign Tests on Conductance Level and GSR. Data reported in Wilson (1966) Table I.

[4] In extreme cases, e.g., when uniformly colored half ping-pong balls are taped in front of the eyes, habituation can produce desensitization. Such extremes, however, do not seem relevant to the situation under review, in which the key measures were taken 12 sec. after onsets of a contrasting color.

This table does not tell us how these cases were distributed; but the fact that the average ranking for first red trials is something over 3 entails that some of these cases happened in the first exposures, i.e., that in some individuals, even on the first exposure to red, its GSR for red was *not* greater than that of the first exposure to green.

These inferences from Wilson's reported data seem decisively to prevent his results from being regarded as supporting the necessary concomitant view. There would appear to be just two hypotheses we might adopt concerning these inferred individual differences.

> (H1) All subjects have the same red experiences and the same green experiences. Red Is more arousing than green for a majority of the subjects, green is more arousing than red for a substantial minority of subjects, and for a smaller minority, the two colors are equally arousing.
>
> (H2) Wilson's subjects included both a substantial number of red-green color inverts, and a smaller number of subjects who have some other peculiarity in their space of color experiences (leading to equal arousal).

(H1) is evidently incompatible with the necessary concomitant view. (H2) is compatible with it, but cannot support it. This is because the only reason one would have to accept (H2) is the view that differences of arousal indicate differences of experience. But to argue for (H2) in this way would be question begging, in any context in which the necessary concomitant view is a point at issue.

The point may be clearer if we observe that accepting the philosophical thesis of necessary concomitance in conjunction with Wilson's results would imply that a significant percentage of people differ in their color experiences and thus, presumably, in their perceptual physiology. This kind of difference is, of course, an empirical possibility; but to accept it on the ground just sketched would be a case of metaphysical needs dictating what science ought to find. Such imposition would be found objectionable by many, including those who are inclined toward the necessary concomitant hypothesis.

We may conclude that Wilson's results offer *no support* for the necessary concomitant view. We may say also that *unless* one accepts that some of Wilson's subjects were red-green inverts, his results support rejection of the necessary concomitant view.

A natural reaction to the points just made would be to say that (a) Wilson's central finding shows that there is a hue-arousal connection in all subjects, but (b) the record of this effect is obscured in some trials by extraneous factors, e.g., some subjects might have happened to think of something irritating or otherwise arousing during the 12 sec. after a green onset.

Such extraneous factors are, of course, possible; but this possibility cannot be used to turn Wilson's experiment into *empirical support for* the necessary concomitant view. For, if it is allowed that ideation can influence GSR, then that possibility must be allowed for red trials also. It is, in fact, a plausible hypothesis that the contingent facts of the world have created associations between red and such things as fire, or fresh blood. Such contingent associations are quite compatible with the contingent concomitant view, but they are inimical to the necessary concomitant view. For example, in inverted spectrum contexts, such contingent associations would associate arousal to green experiences; and this is precisely what the necessary concomitant view is supposed to rule out. It would, evidently, be *ad hoc* special pleading to allow ideational effect for green onset trials while excluding such effects in the case of red onset trials.

Let us be clear that we are not rejecting Wilson's effect. The rejection of the necessary concomitant view is perfectly compatible with accepting the contingent concomitant view. We may hold that, as a matter of contingent fact, a majority of people are, for whatever reason, possessed of brain conditions that make the causes of red experiences also cause (a relatively large increment of) arousal, while some other people's brains are not so arranged. The difference between these views is of no direct interest to psychologists in so far as they are investigating psychological connections. It is, however, of crucial interest in a context in which it is implied that we cannot distinguish hue qualities from total responses (including arousal) to stimuli such as colored lights.

## 4. A Non-Experimental Interlude

Imagine a case in which people view a ripe Delicious apple and a ripe avocado lying side by side on a tablecloth of neutral color. What should we expect about their arousal upon first exposure to this scene? My own expectation would be that there would be no change in arousal. Perhaps some will think that arousal should be elevated (because of the red) but only a little, to a small value intermediate between a pure red case and a pure green case (because of the offsetting pull of green toward low arousal). In either case, the arousal level for red would be missing. But it is implausible that in such a case, subjects must have a red experience that differs from the red they would experience if the avocado were not present.[5] Thus, we have an argument (although not an experimentally based one) for separating hue from arousal. This argument puts the burden of proof on those who would hold that there is a necessary connection between color and effect upon arousal.

## 5. Gerard's Experiment

R. M. Gerard (1958) exposed 24 subjects to ten-minute presentations of red, white, and blue colored lights, each preceded by a color preference period of less than 30 sec., and a rest period of 12 or 8 minutes. The lights were back-projected onto a circular translucent screen of 13 inches diameter, located 50 cm. from the bridge of the subject's nose. Subjects were otherwise surrounded by black curtains and black cardboard. Transmitted radiant flux for blue, white, and red presentations were 435 - 505 m:, 400 - 760 m: and 600 - 690 m:, respectively, with peaks at 465, 510 and 625 m:. The projector used 500 watt bulbs and its lens was 87 cm. from the screen. Transmittance of the screen was 37% (constant over wavelengths). Brightness for the different colors was equated through the use of seven trained observers in a preliminary procedure. Median brightness of the translucent screen during color presentations was 4.2 footlamberts, contrasting with 1.04 footlamberts of the dim white light projected during the rest periods. Subjects were

[5] Surrounding a red spot with a green background would significantly change the character of the red experience (see Albers, 1963). In the case I have described, however, the interaction of colors should be virtually nil.

tested for normal color vision, and then randomly assigned to groups of four, with each group receiving presentations in one of the six possible orders for the three colors.

In Wilson's experiment, data were reported in a somewhat summary fashion. It should be well noted that Gerard's work is quite the reverse, with every aspect reported in full detail. In the preceding paragraph, and in those to follow, the present author has undertaken to report accurately and fairly all information that is relevant to the limited purposes of the present discussion, but the informational content relative to Gerard's 280 page dissertation has been reduced by at least two orders of magnitude.

In the color preference period, subjects were exposed to one of the experimental colors and asked to rate their immediate reactions on a four point scale ranging from "very pleasant" to "very unpleasant". Subjects were then measured during the rest period before each of the color presentations, and during the color presentations, on the following dimensions: systolic blood pressure, palmar conductance, respiration rate, heart rate, frequency of eyeblinks, percent of time that Alpha waves were present, and peak microvoltage of Alpha amplitude. Subsequent to the last color presentation and disconnection of the measuring apparatuses, subjects were asked to rank their feelings during the three colored illuminations. A form for reporting comparisons of "the way you felt during the different colored light presentations" on 28 items was provided. This form permitted a ranking, with 1 corresponding to "more", 2 to "in between" and 3 to "less" on the indicated item. Items that seem most relevant to the concerns of this paper were: Alert-awake, Brightness of lights, Calm-peaceful, Cheerful-happy, Cool-cold, Excited-aroused, Irritable-annoyed, Pleasant thoughts and associations, Unpleasant thoughts and associations, and Warm-hot. Following these rankings, subjects were given a half page each to report what their thoughts and associations were during each of the three colored illuminations; what each light reminded them of; the nature of their daydreams, feelings, moods, and bodily sensations. The final half page of this report asked for comparisons of sensations, moods, feelings and thoughts during the three illuminations. Finally, subjects were asked to rate, on a four point scale, the degree of experienced relaxation or tension during presentation of each light, and the degree to which each light was soothing or irritating.

Measures taken during the three resting periods (i.e., the12 or 8 minute periods of dim white light on the screen immediately prior to the ten minutes of bright experimental color) were analyzed. Levels for these measures were found to be homogeneous; "they could therefore be used as basic scores in the analyses of variance designed to test the main hypothesis of differential physiological activation under different colored illuminations" (p. 65).

Gerard's prediction for autonomic and muscular measures was that significant changes from resting level activations would be induced by each of the three colored illuminations, and that the order of mean changes would be Red > White > Blue; i.e., red would be most highly activating, blue least, with white in the middle. Except for the measure of heart rate, this prediction was confirmed by the experimental results: "the data support the major hypothesis that differential physiological activation can be induced by different colors" (p. 66).[6] Results for physiological measures for red and blue exposures

[6] Gerard offers a complex explanation of the exceptional nature of the results for heart rate. The present author draws no conclusions from the presence of this exception; hence we will not go into the details of

are shown in Table 2.

| | Red | Blue | Difference | t (difference) (Blue-Red) |
|---|---|---|---|---|
| Systolic Blood Pressure (mm. Hg) | +2.91 | -1.57 | -4.48 | 3.50 $p < .005$ |
| Palmar Conductance (100 Log. C) | -0.27 | -3.32 | -3.05 | 2.48 $p < .01$ |
| Respiration Rate (per minute) | +0.42 | -0.55 | -0.97 | 2.43 $p < .01$ |
| Heart Rate (per minute) | +0.65 | +0.27 | -0.38 | 0.58 |
| Frequency of Eyeblinks (per minute) | +1.65 | -3.47 | -5.12 | 3.03 $p < .005$ |
| Alpha Per Cent (% time present) | -12.55 | -4.11 | +8.44 | 3.03 $p < .005$ |
| Alpha Amplitude (peak microvolts) | -2.77 | -0.88 | +1.89 | 1.93 $p < .05$ |

**Table 2**. Mean Changes from Resting Level and Summary of t-tests. Data for red and blue reported in Gerard (1958) Table VI.

Figure 2 may help to make the red/blue difference clear.[7] Graphs for the other measures are not quite so dramatic, but (except for heart rate) show clear separation between the curves for red and blue.

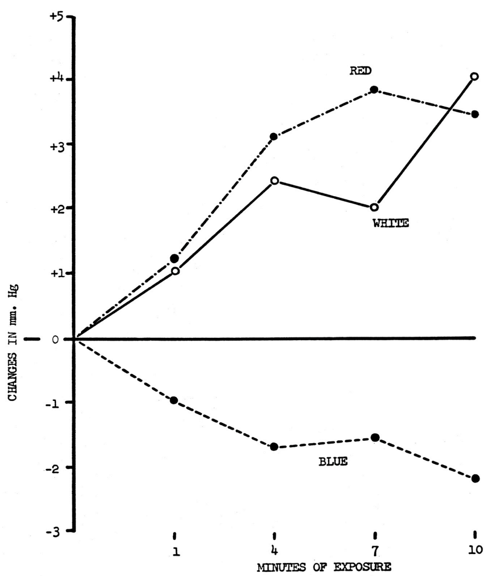


**Figure 2.** Systolic Blood Pressure: Mean Changes from Resting Level. (Reproduced from Gerard (1958) Figure 3, p. 72.)

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Gerard's explanation.

Alpha wave time percents are inversely proportional to cortical activation; thus, while increased activation is indicated by increases in blood pressure, palmar conductance, etc., increased activation is indicated by decrease in time percentage of Alpha wave presence. In the present paper, we always look through this detail and refer to what a decrease in Alpha score indicates, i.e., increase of arousal, rather than the direction of the score itself.

[7] Gerard provides another graph for the group minus one outlying member. This removal of one subject has a noticeable effect on the curve for white, but the red and blue curves remain much the same.

Perhaps the clearest summary picture can be derived from Figure 3, which shows means for several measures, by color, taken over the whole exposure.

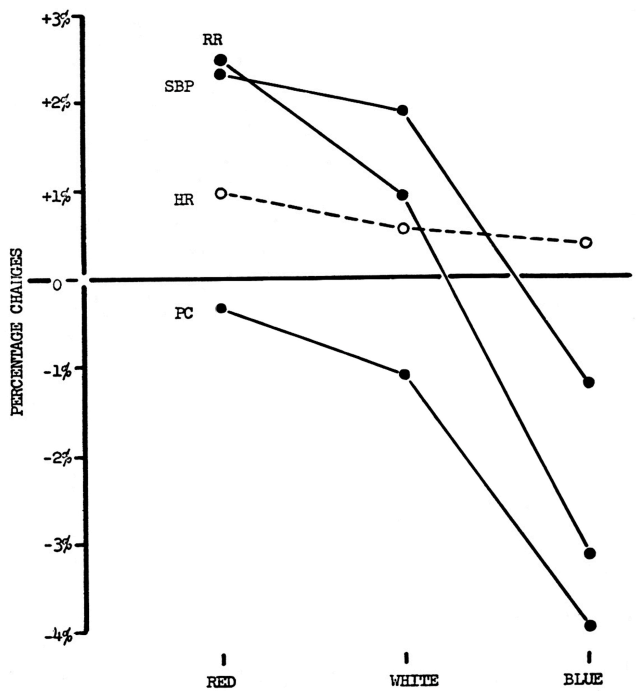


**Figure 3**. Mean Percentage Changes from Resting Level: Autonomic Measures (SBP = Systolic Blood Pressure; PC = Palmar Conductance; RR = Respiration Rate; HR = Heart Rate) (Reproduced from Gerard (1958) Figure 11, p. 88.)

Turning to affective measures, Gerard found that most of his predictions were borne out by the data. If we restrict our attention to the order of red and blue, there were only two exceptions to predicted order, namely, Brightness of the lights (predicted: R = W = B, obtained: R > B = W, $p < .01$) and Tired-fatigued (predicted: W > B > R, obtained: R > W > B, $p < .20$). In general, predictions and data showed red more arousing than blue. Rank order results for the items listed earlier are given in Table 3.

| | | |
|---|---|---|
| Alert-awake | R > W > B | p > .20 |
| Brightness of the lights | R > B = W | p < .01 |
| Calm-peaceful | B > W > R | p < .001 |
| Cheerful-happy | B > W > R | p < .001 |
| Excited-aroused | R > B > W | p < .01 |
| Irritable-annoyed | R > W > B | p < .001 |
| Pleasant thoughts & associations | B > W > R | p < .001 |
| Unpleasant thoughts & associations | R > W > B | p < .001 |
| Warm-hot | R > W > B | p < .01 |

**Table 3**. Data reported in Gerard (1958) tables X and XI, pp. 98 and 99.

Gerard's data support a number of summary statements. Those most relevant to our concerns are the following. "The Ss reported significantly less 'anxious-apprehensive' feelings in blue light than in the other conditions" (p. 102). "The Ss reported feeling significantly more 'excited-aroused' during red illumination" (p. 102). "'Pleasant thoughts and associations' were reportedly induced significantly more during blue illumination than during the other conditions, while 'unpleasant thoughts and associations' were aroused significantly less by blue light than by either red or white light" (p. 102). "Ss reported that they were significantly more 'cheerful-happy' during blue than during the other conditions" (p. 104-105). "Ss reported a significantly greater 'general over-all well-being' during blue than during the other conditions" (p. 105) Despite elimination of infra-red from the red light and very small variation of room temperature during the experiment, "the group reported feeling significantly more 'warm-hot' during red compared with blue illumination and significantly more 'cool-cold' during blue compared with red illumination" (p. 107).

I believe it is fair to compress these results into the summary statement that Gerard's results support the claim of polarity between red and blue colored light illumination, with red being on the warm or high arousal pole and blue being on the cool or low arousal pole. This result concords to a high degree with the results from the physiological measures.[8] Philosophers who say that red is more arousing or more warm than blue are affirming a statement that can be grounded in detailed empirical work.

## 6. Why Gerard's Results Do Not Support The Necessary Concomitance View

### 6.1 Learned Associations

Gerard's subjects were told that the "most important instruction I can give you this afternoon is to allow yourself to respond freely to the colors. If the colors bring certain thoughts and associations to your mind, allow yourself to have these thoughts, whatever they are" (p. 51). Two variants of this encouragement were offered. After completing the affective ranking form, subjects reported the content of the ideation during each of the colored light periods. Gerard reports that "red illumination brought forth a variety of unpleasant associations involving 'blood,' 'injury,' 'fire, heat, danger and pain,' as well as sex and aggression" (p. 119). Blue periods, by contrast, brought forth associations with friendliness, helpfulness, romantic love, blue skies, fair weather, and the blue water of a lake or an ocean (pp. 275-277).

These differences of ideation correlate with the physiological measures. "The data supported the hypothesis that autonomic responses to colored lights covary significantly with the hedonic tone (pleasantness-unpleasantness) of thoughts and associations aroused during exposure to these lights" (p. 118).

The argument to be made on the basis of these data is that differential arousal may be explainable as an effect of differential ideation during the color presentations. Differential ideation may, in turn, depend on learned associations, e.g., of red to fire or blue to sky or water. Learned associations are, however, *contingent associations*, even if, the causal facts being what they are, similar associations are learned by nearly everyone. Thus, if the cause of the physiological arousal is mediated by learned associations, then

[8] Gerard details the degree of concordance in his Table XXI, p. 203.

the polarity effect supported by Gerard's data is no argument for a necessary concomitant view.

Admittedly, Gerard sometimes expresses his covariance result in a way that suggests a different direction of causation. He says, for example, that "the number of significant and near-significant relationships between autonomic measures and affective responses would not be reasonably expected by chance alone, and supports the hypothesis that subjective reactions to color do reflect objective changes in autonomic activity" (p. 110). Again, "Under the conditions of this experiment, affective responses to colored lights involved more than superficial or stereotyped judgments, for they reflected actual organismic states" (p. 137). There is nothing in Gerard's data, however, that supports this direction of "reflection"; and, indeed, at other places the concordance of measures is treated differently. Thus, "Colored lights aroused associated memories of an individual nature such as the blue dress of a beloved girl friend, or red blood stains after an automobile accident. Presumably, these emotionally charged mnemonic events would in turn affect the autonomic nervous system" (p. 141). Again, "covariant physiological changes suggested that affective responses to color may be accompanied by objective changes in the organism" (p. 146). "The findings suggested that psychophysiological responses to color are mediated by affectively toned associations derived from differential learning experiences with different colors" (p. 189).

It may well be argued that Gerard's data entitle him no more to a causal claim in the direction from affective associations to physiological arousal than to a causal claim in the reverse direction. We need not contest the point of such an argument. A neutral position, however, is sufficient to support the conclusion that Gerard's data *do not support* a necessary concomitant view. So long as the direction from affective association to physiological arousal is *not ruled out*, we cannot use Gerard's experiment to dismiss the relevance of learned associations. If we cannot dismiss this relevance, we cannot dismiss the hypothesis that the polarity effects of hue in colored lights are contingent effects; and this is to say that we cannot take ourselves to be supported in a positive affirmation of a necessary concomitant view.

Our result will not be changed if it is held that some associations are not learned in lifetimes, but only "learned" in evolutionary time.[9] This suggestion is most plausible for red: perhaps its association with fire and fresh blood has resulted in its being innately connected to mechanisms of heightened arousal and negative affect. But this kind of connection is still contingent. Allowing it is compatible with holding that our ancestors' perceptual apparatus produced the same hue experiences before the connection to other mechanisms became innate, and it is compatible with the possibility of people with both inverted spectra and inverted connectivity between color perception and arousal or affect.

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[9] Wilson (1966) implies such a suggestion for colors at both ends of the visible spectrum, i.e., red and violet. Nourse and Welch (1971) find evidence consistent with this suggestion for violet; there are, however, several difficulties in interpreting their results.

### 6.2 Individual Differences

Inspection of Gerard's data reveal that several of his 24 subjects ran counter to trend on each of his measures. Table 4 gives the number of subjects running counter to trend on each dimension. The number in parentheses gives an additional number of subjects for which there was little or no difference on that dimension. Additional comments follow to the right. "Lower" means "lower relative to resting condition"; "ND" means "no difference or very slightly lower relative to rest condition". Note that a subject running counter to trend could have either higher arousal than resting condition in the blue condition, or lowered arousal in the blue condition, but not as much lowered as in the red condition.

| | | |
|---|---|---|
| Systolic Blood Pressure | 2 (5) | Lower in red condition in 3 cases, ND in 2 cases |
| Palmar Conductance | 2 (3) | Lower in red condition in 9 cases, ND in 5 cases |
| Respiration Rate | 5 (3) | Lower in red condition in 7 cases, ND in 2 cases |
| Frequency of Eye Blink | 5 (3) | Lower in red condition in 6 cases, ND in 5 cases |
| Alpha Time % | 5 (5) | Elevated in red condition in 2 cases, ND in 3 cases |
| Alpha Amplitude | 8 (2) | Elevated in red condition in 4 cases, ND in 3 cases |

**Table 4**. Subjects running counter to trend, derived from Gerard (1958), table XVIII. (See text for explanation.)

Twenty-one subjects failed to record according to trend (i.e., were either counter to trend or not different between red and blue conditions) on at least one measure. Numbers of failures of trend and numbers of subjects showing that number of failures are as follows.

| | | | | | |
|---|---|---|---|---|---|
| Number of failures of trend | 5 | 4 | 3 | 2 | 1 |
| Number of subjects | 1 | 3 | 5 | 6 | 6 |

**Table 5**. Trend-failure subjects by number of trend failures.

The conclusion I draw from these exceptions to trend is this: *Gerard's data do not support a necessary concomitant view.* This result should not be overstated. Doubtless, if one assumes a necessary concomitant view, one will be able to hypothesize factors that explain why the necessary connection was obscured in many cases. The data themselves, however, are fully compatible with a contingent concomitant view, which allows that there is an alignment of factors in a majority of subjects that leads to a significant finding of greater arousal for the red colored light in that population, but denies that there is any necessary connection between the experience produced by the red light and any of the measures of arousal.

### 6.3 Color Preference

In the initial, brief color preference period before the rest period and subsequent ten minute exposure to a light, subjects were shown the next light they would be exposed to and asked to rate it on a four point scale ("very pleasant", "mildly pleasant", "mildly unpleasant" and "very unpleasant"). Intermediate values were allowed, and additional remarks, if any, were recorded. Results are reported as rankings, with 1 for most preferred, 3 for least preferred. Blue was highly preferred, with its sum of ranks being 29.5; red was least preferred, with its sum of ranks being 59.5. (Since there were 24 subjects, a universal preference for one color would have produced a sum of ranks of 24; and a universal maximum dispreference for one color would have produced a sum of ranks of 72.) Overall preference of the group of subjects of blue over red was significant, p. < .002.

These results suggest that some of the arousal observed during the exposure to the red light was due to dislike of that color. In that case, some of the arousal would be dependent on an evaluative reaction to hue, not simply on the hue experience itself. The result of the color preference question thus suggests another mechanism by which Gerard's main result could have been produced (or, been enhanced) without supposing that there is any necessary concomitance between red experience and arousal.

It could be argued here either that dislike is a necessary concomitant of red light, or that dislike was due to irritation with the red light, which latter property is a necessary concomitant of it. In either case, the color preference result would not be very important, because arousal could be taken as showing necessary concomitance of *something* with red, even if it is not perfectly clear exactly *which* property is, in the first instance, the necessary concomitant. It is conceded that this possibility is not *disproved* by Gerard's data, nor by the argument of this paper. However, (a) there are some data that count against it, as three of the 24 subjects preferred the red light to the blue light. Of course, we might take these subjects to be color inverts, or we might hold that there must be some mechanism that overcomes the dislike or irritation that is associated with red, and is present even in these cases. But barring these question begging and *ad hoc* assumptions, these three subjects can be regarded as tending to disconfirm the view that an evaluative response is a *necessary* concomitant (as opposed to a frequent, contingent concomitant) of red lights. And in any case, (b) it is evident that the moves we have imagined to be made in defense of the necessary concomitant view are attempts to explain the data away, and not explanations that could be claimed to be *based upon* Gerard's data. In other words, the color preference result is data that tends against the necessary concomitant view, even though it does not disprove it.

### 6.4 Retinal Quanta

As noted, the colored lights were equated for apparent brightness in a pre-experimental procedure.[10] Such judgments, however, are not a linear function of the number of quanta reaching the retina. Gerard (1958, p. 116) explains how he arrived at an estimate of

[10] Despite the preliminary attempt to equate brightness, rankings of the brightness of the lights by the experimental group showed a significant difference for red as being brighter than white or blue (with the last two being not significantly different). However, this difference seems small, is based on reports taken retrospectively (after the last light and after disconnection from the apparatus), and may have been influenced by the ideational differences already commented on in section 5.1. For these reasons, this paper makes no suggestion that experimental results depended on differences of apparent brightness.

relative number of quanta reaching the retina in the three colored light conditions. Setting blue = 1.00, the relative numbers for red and white were 7.53 and 5.67, respectively. Gerard (p. 143) notes that these values may fail to reflect changes in size of pupil in the different conditions.

The relevance of the difference in these estimates is hard to evaluate, and not too much should be made of it. It might not be worth mentioning at all, were it not for the fact that the order of relative quanta was the only aspect of the stimulus that paralleled the pattern of physiological activation. In light of this fact, we should consider it *possible* that some important fraction of the reported results is due to difference in quanta at the retina.

Suppose this possibility is taken seriously. It may still be argued that the difference in numbers of quanta made a difference by determining the hue, and thus, that hue is the mediator of whatever effect may attributed to the difference in retinal quanta. This auxiliary hypothesis would be consistent with a necessary concomitant view. It is also possible, however, that differences in retinal quanta have an effect on the visual system through pathways *other* than those that contribute to production of the hue involved in various experiences. According to this alternative auxiliary hypothesis, there would be a factor in the reported results that was independent of hue, and the relevance of the experiment to the concomitants of experienced hue would be reduced.

It does not seem possible to evaluate these competing auxiliary hypotheses, and so this paper advances no positive claim on the basis of differences in retinal quanta. The evidential situation does, however, support a recommendation of caution. Difference of retinal quanta *could* be a confound that would weaken the connection between hue and arousal, independently of the other sources of such weakening that we have reviewed in this section.

### 6.5 Summary of Conclusions from Gerard's Experiment

Gerard offers support for a correlation between hue differences and arousal differences. If we make only a general statement that red colored lights are likely to be more arousing for most people than white or blue lights of equal brightness, we will find support in Gerard's work. We will not find support, however, for the much stronger claim that higher "warmth" (relative to blue), that is, elevation of arousal in one form or another, is a necessary concomitant of red hue presented as colored light. The data are compatible with a contingent concomitant view, according to which the connections between hue systems and arousal systems are different in different individuals, and can be influenced by learned associations, learned preferences, and perhaps other factors. It may be that special assumptions would enable one to reconcile a necessary concomitant view with Gerard's data; but support for the necessary concomitant view from *within* Gerard's experiment cannot be found.

## 7. Considerations for Functionalism

Using Wilson's (1966) results and Gerard's (1958) results to support an association between experiencing red lights and having elevated arousal makes sense if we apply the association across populations. Suppose, for example, that we were to repeat these experiments in several universities, and we found the results to replicate on the West coast, but not on the East coast. This (extraordinary and entirely fanciful, but logically possible) outcome might persuade us that California was an even more special place than we might already have thought. Some difference among the populations might reasonably be hypothesized – although, for reasons given above, it would be question begging to attribute the difference to coastal color experiences rather than a difference in the contingently related arousal reactions to those experiences.

Experiences, however, are agreed by all parties to the discussion to be particular occurrences in individual subjects. A functionalist account of, e.g., red experience must identify a function for red experiences, such that anything that is to be identified with a red experience must satisfy that function in the individual in whom it occurs. Our analysis shows that, at the very best, the studies we have reviewed offer no support for including arousal as part of the function of red experiences.

We may apply these reflections to the case of inverted spectra. Those who hold a necessary concomitant view will be apt to think that a color invert could be detected by discrepancies in arousal. They would agree that two inverts' verbal reports of colors of things might be identical, and so their difference would not be evident in ordinary contexts. But the invert would stand out if the color of fresh blood were rated less "warm" than the color of Yale banners, or if physiological measures showed more arousal for the latter than the former. The upshot of our discussion is that such conclusions would be ill grounded. Unless we make the *ad hoc* assumption that the experimental subjects who ran counter to the overall trends were color inverts, we should agree that finding a subject who ran counter to the norm would *not* legitimately be taken to be discovery of an invert; for that subject might just as well be a normal hue subject whose life experiences have resulted in counter associations, or whose innate connections from color perception to arousal or affect are reversed. And if that is possible, so are genuine inverts who go undetected because *their* life experiences have resulted in counter associations to their inverted spectra, or because they have reversed innate connections; that is to say, their arousal profiles would match the majority of those giving the same verbal color reports, despite their hue inversion.

The moral concerning functionalism can be generalized. A function may be described in a highly general way, that is, a way that will leave room for many realizations. For example, giving the function of a pump as moving fluids from one place to another leaves wide open both questions of material of construction, and questions of design (rotary, piston, etc.). Functional descriptions may be narrowed in many ways; for example, we may specify that a job is to be done with the use of certain materials, that it be done by using certain design elements, or that it be done within certain time constraints. Narrowing a specification in general leaves open multiple realizations, but fewer possible realizations than wider specifications.

One conclusion that our examination forces upon our attention is the well-known fact that human beings exhibit individual differences in their behavior and in their psychological processes. Wherever we agree that many people have a cognitive or perceptual ability, we must recognize that there will be a limit to the specificity of a functional characterization of that ability. That is, we cannot narrow the time or resource constraints so severely that some individuals who appear to have the ability in everyday life will be arbitrarily ruled to fall outside the stated constraints.

In these terms, the conclusion we have reached in this paper is that the functional characterization of having a red experience cannot be drawn so narrowly as to exclude people who would ordinarily be taken to have red experiences; and respecting this constraint plausibly keeps the characterization wide enough to allow for individual differences in the arousal reaction. Or, at least, drawing the functional characterization of red any narrower that this would be arbitrary in the absence of some further, compelling argument.

Let us look at the matter from a nonfunctionalist point of view. Red experiences are something, and something different from green experiences. Since they are bounded realities, they have causes. The contingent concomitant view holds that there can be causes of red experiences that are not causes of increases of arousal. This view allows, in a very natural way, that in some brains the surrounding connectivity is such that in the experimental circumstances an event that causes a red experience is also sufficient (in conjunction with surround) to produce an elevation of arousal. This view also is quite compatible with the finding that such brains comprise a majority. When we put the matter in this causal and contingent way, however, there will be little temptation to conclude that a brain in which elevation of arousal is not triggered must be a brain that does not contain the causes of red experiences.

It would be possible to adopt a policy of tailoring the functional specification of red experiences so that it rules in, as satisfiers of the function, exactly those events that would be viewed as causes of red experiences by those who take a nonfunctionalist approach. However, to adopt such a policy would be to trivialize functionalism, i.e., to remove its point.

Such a trivialization would not result from the mere fact that the two approaches arrived at the same set of events. It would arise, rather, from adoption of a *policy* of tailoring descriptions of functions so as to make such convergence a guaranteed result. To avoid such a trivialization, a functionalist approach must have a *principled* way of specifying the function of red experiences (for example) that allows for individual differences in responses and does not reduce to a procedure of first identifying the causes of red experiences and then using that identification to define the function. I have no general argument that shows that these requirements *cannot* be met; but nor am I aware of any account of how to provide such a principled specification for sensory experiences that will serve the purposes for which functionalism is typically invoked.

## 8. Toward Generalization of these Results

We may conceive of the generation of color experiences as normally involving a process involving neurons at several synaptic removes from the retina. At each axonal termination, there is the potential for neurons to synapse not only onto neurons that continue the pathway that leads to the generation of color experiences, but also onto neurons that project elsewhere. For example, there are projections from the LGN not only to V1, but to other areas of the brain. It is always possible that arousal or affective states are products of these parallel projections, and not products of processes that proceed all the way through the color experience pathway to the actual generation of color experiences. In these cases, we might expect significant correlation between arousal and affective states and color experiences, even though the processes that generate them overlap only partially and therefore are capable of being dissociated by differential blockage of pathways after the point of separation.

It is also possible that some responses are generated by pathways that have significant post-color experience components, and that these later components could be blocked or altered without change in the earlier components that generate color experiences, and hence, without change in color experiences.

In both of these cases, we might expect correlation between color experiences and arousal or affect, *without* having any reason to think that the color experiences are inseparable from, i.e., necessarily inclusive of, the arousal or affective phenomena. In short, these cases provide models for *contingent* concomitance. It seems to this author that it is very difficult to obtain evidence that would rule out such models. Unless they are experimentally ruled out, however, experimentally supported correlations between hues and arousal or affective states cannot be considered as showing more than a contingent relation between these aspects of our experience.

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