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Letter to the Editor

Is a unified model of contrast and constancy possible? Reply to Gilchrist

1. Nothing to debate: "Frameworks" vs "layer" models

1.1. Unifying constancy and contrast

Responding to my critique of anchoring theory, Gilchrist states that "Perhaps the most important ongoing debate in lightness theory is that between layer models. . .and framework models. . .." He suggests that both outlooks succeed and fail in complementary ways. But Gilchrist's criterion for failures of layer models seems contingent on taking as a given what is actually the anchoring theory's central theoretical claim: that "background-dependent errors" (referring to contrast effects) and "illumination-dependent constancy errors" (referring to failures to properly factor relative illumination into the lightness estimate) result from a common underlying mechanism (Gilchrist et al., 1999). This unification was to be achieved via a functional unit called the "framework." However, the effort has failed to produce a set of testable, unifying assumptions. Not only has anchoring theory failed to incorporate the perception of transparency into its theoretical framework; it has also, as Gilchrist acknowledges in his response, failed to produce a principled account of simultaneous contrast. Furthermore, its account of illumination-independent constancy is oddly vague and incomplete. If there are no convincing theoretical arguments in favor of the unification of contrast and constancy effects, then layer models cannot be faulted for not simultaneously attempting to explain both.

1.2. Frameworks and layers in models of lightness

The core of the putative debate between framework and layer models is described by Gilchrist as follows: "Layer models parse the image into overlapping layers, with an upper layer representing perceived illumination or transparency and a lower layer representing surface reflectance. Framework models typically parse the image into adjacent frameworks, much like different countries on a map. . ." The distinction being made here is dubious for a number of reasons.

First, Gilchrist seems to be confusing theory with fact. It is the visual system, not theory, that parses the visual experience into overlapping layers representing illumination/transparency and underlying surfaces. Layer models, whether they succeed or fail, simply attempt to specify the conditions under which such layering occurs, and its consequences for lightness. Frameworks models cannot theoretically dislodge perceptual facts, so these facts cannot be considered a point of contention or debate. Indeed, accurately describing the facts to be explained is the first step in any theoretical formulation. Ignoring them, on the other hand, is unlikely to produce powerful models or theories.

Second, even layer models necessarily involve the segregation of the visual field into areas that are adjacent, like countries on a map. The impression of transparency, for example, is contingent on perceiving only part of the visual field as being under the transparent layer. No model of perception can deny that the visual field is perceptually segmented into adjacent areas. So a simple reference to "frameworks vs layers" implies no ground for debate between the anchoring model and any other model of perception. As with layers, adjacency is a perceptual fact, not a theoretical assumption.

Third, it is not the case that "frameworks models" do not parse the image into layers. The most obvious case is the model described by Bressan (2006) with its reference to the "overlay framework" in transparency illusions. Layering theorists refer to "transparent overlays." Does Bressan's anchoring theory really preserve a meaningful distinction between "frameworks" and "layers"? Even without Bressan's model, anchoring theory cannot avoid layers. As described by anchoring theorists, frameworks are not merely adjacent, like countries on a map. They are also overlapping. For example, the target and background units in the classic simultaneous contrast illusion, referred to by anchoring theory as "local frameworks," involve the amodal completion of the background behind the target. At the same time, these units exist within larger frameworks, and ultimately within the "global framework." This latter is amodally completed behind all of the subsidiary frameworks. So we are obviously talking about segregation in depth, or layering, as well as adjacency. Anchoring theorists also refer to depth boundaries, including occlusion boundaries, as segregating factors. Again, this implies opaque, overlapping layers. Finally, in discussing the "area rule," Gilchrist (2006) refers to "perceived area," thus including the amodally-perceived, lower layer in the area estimate.

The fact that the anchoring theory has addressed only opaque layers and not non-opaque layers, i.e. has declined to attempt a "frameworks of transparency" account analogous to its "frameworks of illumination", despite a deep literature, both historic and contemporary, on the factors that trigger transparency, is not grounds for a debate with models that do make this attempt. Obviously, any account of transparency would need to include terms for both the underlying surface and the transparent layer (as, via the area rule, anchoring theory does for opaque layers) since each has its own perceived reflectance or lightness. A unifying model, in other words, is necessarily a layer model.

In sum, the statement that there is a debate because frameworks parse the image [only] into adjacent frameworks while layer models parse it [only] into layers is not accurate and does not define any specific grounds for debate between "frameworks" and "layer" models. Both parse the image into areas that are

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adjacent and into areas that are segregated by depth and overlap. The anchoring model of Gilchrist et al. (1999) claims to explain contrast as well as constancy effects (and correlated errors), but cannot explain the constancy of surfaces beneath transparencies. Layer models address the latter but do not address contrast. However, they are not obliged to do so in the absence of compelling arguments in favor of a unified model. Only the anchoring model proposes to make such arguments. The burden is on it to show that contrast, illumination, and transparency effects can be unified under a single theoretical framework. Lacking a coherent account even of contrast (see below), it would seem to be in no position to defend a unified account assumption.

2. Edge classification

In my critique, I suggested that, in contrast to its original claims, the frameworks of anchoring theory had come to be defined on the basis of edge classification. This notion was based on references to "frameworks of illumination" and various statements indicating that according to the anchoring theory, "the retinal image is segmented into frameworks based on two main factors: fuzzy boundaries and depth boundaries (corners and occlusion boundaries)" (Zdravkovic, Economou, & Gilchrist, 2012, p. 782). In other words, segregation into frameworks is currently being described as relying mainly on factors typically correlated with illumination boundaries. Gilchrist responds that "edge classification retains an important role in anchoring theory, but is supplemented by grouping processes."

Gilchrist's statement implies a false dichotomy between edge classification and grouping processes. As with every aspect of the organization of the visual field, edge classification is based on grouping principles. The role of X-junctions, for example, is contingent on the rule of continuity, which explains why we refer to "X" and not "V-plus-upside-down V-junctions." Thus, Gilchrist's statement does not help to clarify the assumptions of anchoring theory.

As regards the role of edge classification per se, anchoring theory's references to depth boundaries and fuzzy boundaries constitute a very partial description of the known factors underlying the organization of the visual field into areas perceived to differ in their illumination. There exist much more nuanced descriptions of these factors (within the context of layer models, for example). Fuzzy boundaries and depth boundaries are not necessary to edge classification, as illumination boundaries may be perceived in the absence of these factors. They are also not sufficient: depth boundaries and fuzzy boundaries in no way guarantee that areas on either side of the boundary will be perceived as differing in their illumination. For example, we do not perceive the sides of an all-white Necker cube to differ in their illumination; if we did, then at least one of the sides should appear luminous or whiter than white. Fuzziness obviously is too crude a term to specify the requisite contrast relationships that need to hold if a boundary is to act as an illumination boundary. In addition, anchoring theory has not resolved apparent failures of a penumbra to segregate regions, e.g. when a section of a surface under a shadow is perceived to share the color of the surrounding surface.

It might be argued that the above-cited statements are a shorthand for an actually better-developed model of edge-classification, but this does not seem to be the case. Given the devil-in-the-details masses of lightness observations reviewed by Gilchrist et al. (1999) and Gilchrist (2006), it seems odd for anchoring theorists to be satisfied with such vague terms.

However the visual system manages it, there is no doubt that correctly discerning illumination boundaries is a necessary part of achieving reliable lightness estimates, nor that incorrectly discerning them produces lightness errors. Even if anchoring theory were to produce a complete or novel account of edge classification, this would not be equivalent to unifying contrast and constancy.

Finally, it is not appropriate to attribute to anchoring theory (as Gilchrist does) the insight that visual system does not (cannot) directly estimate illumination level. That the visual system relies on luminance ratios, rather than on local luminance per se, to assign lightness values to surfaces is a direct consequence of the impossibility of estimating illumination directly. If the visual system were able to assess illumination directly, then pictorial illusions of lightness constancy would not occur. These illusions constitute empirical proof that illumination is not directly estimated.

3. Simultaneous contrast

In his response, Gilchrist acknowledges that I "may have spotted a previously unnoticed. . .contradiction in the theory" The contradiction concerns how the classic simultaneous contrast demonstration is said to be segregated into "frameworks."

Attempting to resolve the apparent difficulties of the theory in justifying the primary grouping of target and background, Gilchrist states that each target is grouped with its background "based on the important factor of surroundedness." Further on, he refers to the reinforcing effect of "adjacency plus surroundedness." This is not a defensible claim.

Surroundedness is neither necessary nor sufficient to produce simultaneous contrast. In the "dungeon" illusion (Bressan, 2001), for example, targets fully surrounded by white lighten while those fully surrounded by black darken. In the case of the Benary cross and White's illusion, contrast effects – quite strong in the latter case – arise without surroundedness. The problem is that the surroundedness/adjacency construction is local and thus structure-blind. (While in his response, Gilchrist notes the need to take account of "the larger configuration" rather than "solely at what is happening at a local edge," this general acknowledgment does not seem to inform his specific explanations.)

In each of the above-cited examples, contrast effects are linked to perceived figure–ground relationships. In other words, contrast arises between targets and their perceived backgrounds, not simply between targets and retinally adjacent or surrounding areas. (Since the target in the simultaneous contrast illusion is seen as lying on top of the background, Gilchrist must be referring to retinal rather than perceived adjacency). The correlation between contrast and figure–ground effects is very well established. At the very least, it is more widely-applicable and less spurious than the surroundedness/adjacency claim.

Gilchrist himself contradicts the adjacency-surroundedness proposal in various discussions. In his explanation of "reverse-contrast" illusions, grouping of non-adjacent patches is said to be based on the alignment of their edges (Gilchrist, 2014a) while non-adjacent patches in the dungeon illusion are said to group on the basis of similarity (Gilchrist, 2014c).

In sum, according to the anchoring theory, the targets in the simultaneous contrast illusion should be grouped with each other based on the fact that a. their edges are aligned; b. they appear coplanar with each other (a strong grouping factor according to Zdravkovic, Economou, and Gilchrist (2012)); c. they are similar in shape, reflectance and luminance. An occlusion boundary segregates them from their backgrounds. In their turn, the backgrounds are a. mutually aligned; b. coplanar; c. adjacent, and d. share a sharp boundary (a strong grouping factor according to Gilchrist et al. (1999)) and so should be strongly grouped with each other. Yet the targets are said to be more closely grouped with their backgrounds than either targets or backgrounds are with each other. Anchoring theory's account of simultaneous contrast, a

cornerstone of its stated goal of unifying "background-dependent and illumination-dependent errors" thus fails on its own terms. (This is not to say that the target-background grouping is not self-evident, only that anchoring theory cannot explain it.)

(Gilchrist's observation that there are apparent contradictions in observed contrast phenomena is no excuse. The role of theories is to resolve apparent contradictions in the rules governing natural phenomena, not to reproduce them in the form of contradictory theoretical assumptions. In the latter case, they are not apparent, but actual contradictions of the theory).

If one of the aims of the anchoring model is to model simultaneous contrast, it would seem more practical to attempt to establish the structural factors leading to the perception of the figure–ground relationship – the perceived figure–ground relationship being the most reliable known predictor of contrast effects. (This applies even to surfaces bounded by contours perceived in the absence of luminance differences, i.e. illusory contours.) As in the case of edge-classification, the issue has been much studied. It is not enough for Gilchrist to claim, in his response, that "there is nothing in anchoring theory to prohibit a role for figure/ground" in lightness perception." It is one thing not to "prohibit" a role for figure–ground and another to construct a role for it in the context of a unifying theory. A role for figure–ground is almost never proposed by Gilchrist in his various accounts of the basic simultaneous contrast demonstration, where the figure–ground relationship between target and ground is self-evident. Instead, he substitutes references to surroundedness and adjacency (Gilchrist, 2014b) or "belongingness" (Gilchrist, 2014c), a term which lacks the perceptual clarity or ecological relevance of "figure–ground" and is conceptually at odds with the segregating nature of figure–ground organization. As I noted in my critique, Gilchrist (Gilchrist, 2014b; Gilchrist, 2014c) has also recently suggested that the effect is based on the similarity of the backgrounds to spotlights or shadows, due to their "strong, continuous sign." This formulation also defies the self-evidence of the figure–ground structure, in which the target appears layered on top of the background. And as with the surroundedness/adjacency formulation, it fails (where the figure–ground account does not) in the case of many known contrast illusions, including the dungeon illusion. Again, the anchoring model does not seem to offer a unified account even within the domain of simultaneous contrast effects.

There is no a priori reason to reject the view that simultaneous contrast is functionally distinct from constancy, with its own process based on natural selection for the distinct goal of enhancing the discriminability of figures from their backgrounds. This possibility is acknowledged by Kardos (1934) when he states that "contrast, although it falsely suggests color difference where in fact there is color equality, may in some circumstances be very useful to object vision as border contrast" and that "Hering considered this performance especially important" and a primary function of the "complementary dependence" of surface appearance in contrast effects (p. 79). If contrast and constancy, arise in different contexts, produce different perceptual results, have potentially different functions and if the anchoring theory has not succeeded in unifying them, then it is not clear why this view should not remain part of the debate.

4. Anchoring

In any given situation, the visual system cannot simply assign relative lightness values, it must assign specific values to surfaces, and so must have an "anchoring rule." For a number of reasons, researchers past and present, including anchoring theorists, have endorsed Wallach's (1948) proposal of a "highest-luminance-white" rule for most typical situations. However, in the context of anchoring theory, the application of the rule is supposed to be contingent on the segregation of the visual field into the functional units called "frameworks." Furthermore, these frameworks are supposed to vary in their strength or weakness in a principled manner. Finally, as shown above, they are, de facto, multiply overlapping. As the anchoring theory has evidently not worked out a coherent frameworks account of even a relatively simple stimulus such as the simultaneous contrast demonstration, since its account of edge classification is vague, and since it is unable to deal with areas we might call "frameworks of transparency," it is difficult to see how it can effectively apply an anchoring rule to any given visual image. The problem is not, as Gilchrist suggests, a failure to "completely operationalize" the theory, but the absence of a coherent set of qualitative assumptions.

5. Arroyo, Annan, and Gilchrist (1995) vs. Radonjic and Gilchrist (2013)

Gilchrist does not see a contradiction between the "critical test" cited in Gilchrist et al. (1999) and the findings and assertions of Radonjic and Gilchrist (2013). As I have described it, the contradiction is simple. In the second instance, a visible penumbra produces target lightness estimates consistent with lightness constancy, in the first instance it does not.

6. Allred et al. (2012)

I noted that anchoring theory assumptions do not seem able to account for a stimulus, consisting of a set of coplanar squares producing the impression of illumination and/or transparency effects, used by Allred et al. (2012) and described by them as consistent with the anchoring theory. This statement was not challenged by Gilchrist. Gilchrist also objects to my suggestion that the lower contrast ratios within sections of these stimuli are consistent with transparency. However, the observation that transparencies that both transmit and reflect light reduce the contrast of the underlying surfaces is not new. It is mentioned, for example, by Kardos (1934), who states that this type of transparency "changes the initial lightness proportion between the infield and the surround field in such a manner that their lightness values get nearer to each other."

7. Unfalsifiable yet failing

The anchoring theory proposed by Gilchrist et al. (1999) aimed to offer a simultaneous account of constancy and contrast on the basis of a functional unit called the "framework." This unified account has not emerged. Instead, the frameworks approach has produced multiple ad hoc accounts. While often contradicting each other (i.e. falsifying each other), failures of these ad hoc accounts are not registered as failures of the frameworks concept, because, defined no more concretely than as any de facto perceptual grouping giving rise to lightness effects, it is valid. This is why, as Gilchrist points out, I fell into the apparently contradictory position of saying both that the theory was unfalsifiable and that it was constantly failing. Its umbrella frameworks concept is not falsifiable because it is true as far as it goes. But it is uninformative as to the specifics of lightness estimation. It is its specific subsidiary assumptions, meant to provide the missing theoretical content, that fail consistently. These failures include, in addition to the Arroyo, Annan, and Gilchrist (1995)/Radonjic and Gilchrist (2013) conflict, inconsistent findings regarding the role of figure–ground by Economou, Zdravkovic, and Gilchrist (2007); regarding luminosity by Radonjić et al. (2011); regarding articulation by Radonjic and Gilchrist (2013); regarding the Gelb effect by Ivory and Gilchrist (2014).

8. Conclusion

There is, at present, no working definition of anchoring theory's "frameworks" – how their shape, strength, mutual influence are determined – which anyone, including Gilchrist, can test, modify, or compare with other proposals. Is there any reason to believe that a single functional unit or principle of visual organization can unify contrast and constancy? Anchoring theory has not made the case. Absent a working definition of frameworks, there can be no "anchoring theory of lightness" – research invoking anchoring theory is ostensibly free of coherent theoretical constraints. The mass of historical observations reviewed by Gilchrist (2006) and those accrued since remains undigested.

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