CHAPTER 6

The Hermann Grid Illusion

The history of the development of the Hodgkin–Huxley theory of the action potential provides one detailed illustration of singular compositional abduction. This supports the claim that there exist scientific uses for such abductive inference. The philosophical importance of singular compositional abduction will, however, be enhanced insofar as there are grounds for thinking its use extends beyond this case. One basis has been the brief review in Chapter 4 of intralevel experiments that *prima facie* appeal to compositional abduction. Another basis provided here is an additional case study somewhat removed from the study of the action potential.

Central to this next case study are many intralevel experiments in which scientists present a participant with some visual stimulus and then measure that participant's response. The individual responses constitute data that are aimed at results regarding what the participant perceives. These are psychophysical experiments in which scientists manipulate a participant in an experiment and measure a response, then hypothesize some perceptual activity. The perceptual results – the instances of perceptual activities – are then interpreted in terms of entities whose activity instances are hypothesized to compositionally produce visual perceptions.

Recognizing the role of psychophysical experiments in the study of the Hermann grid illusion suggests that compositional abduction may also play a role in psychophysical experiments generally. In Chapter 1, I noted one problem with the use of case studies: How can one generalize from one or a few cases? As an answer, I proposed that one refer to features of the case that are to be found in other cases. Here I have indicated what I take to be a feature of the study of the Hermann grid illusion that may support its generalization to other cases.

Section 6.1 presents the initial description and explanation of the Hermann grid illusion in Hermann (1870). Section 6.2 then turns to the standard textbook account of the illusion in terms of RGCs introduced in Chapter 4. Section 6.3 describes some experiments abductively

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Figure 6.1 Simultaneous contrast. The medium gray boxes on the left and the right are physically the same but are perceived differently due to the surrounding context.

supporting the RGC hypothesis, whereas Section 6.4 describes some that challenge it. The goal of this case study is not to show that every experiment that is relevant to the grid illusion is an instance of singular compositional abduction. Obviously, the study will only be a partial review of the literature that has touched upon the illusion. The modest goal here is to make a case that singular compositional abduction has had a significant role in the scientific study of the Hermann grid illusion. Indeed, Section 6.5 argues that not all instances of scientific hypothetical reasoning about experimental results directed toward compositional hypotheses should be construed as compositional abduction. It will broach the idea of singular interlevel abduction.

6.1 Ludimar Hermann's Report of the Grid Illusion

Recall from Chapter 4 that, in one version of the Hermann grid illusion, there are intersecting vertical and horizontal white bars on a black field wherein scintillating gray smudges appear at the intersections peripheral to the viewer's fixation point (see Figure 4.3, Chapter 4). In his discussion, Hermann supposed that there are two features of the illusion that are to be explained: (1) there are smudges at the crossing points of the white bars and (2) the smudges appear only in peripheral vision.

Hermann's explanation of the illusion involved two hypotheses: there are retinal elements that produce simultaneous contrast and these retinal elements are sensitive to spatially limited regions. Simultaneous contrast refers to the fact that the perception of the lightness of one region is influenced by the lightness of an adjacent region. For example, in Figure 6.1, a medium gray box of a given luminance is perceived to be darker when surrounded by a very light gray region (on the right) than when surrounded by a very dark gray region (on the left). All this despite the two medium gray boxes being qualitatively the same. The second

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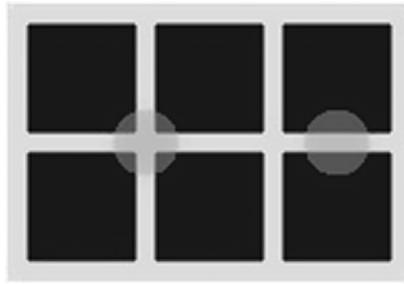


Figure 6.2 Hermann's explanation of the smudges at crossing points: There is more black in the circular region on the right than in the circular region on the left, so the region on the right has more brightening by simultaneous contrast than does the region on the left.

hypothesis is that the retinal elements that influence the perception of a given region are limited in size.[1] Thus, in Figure 6.1, the light gray field on the right has a greater influence on the right-hand medium gray box than it does on the left-hand medium gray box and the very dark gray field on the left has more influence on the left-hand medium gray box than it does on the right-hand medium gray box.

With this background, Hermann's explanation of the smudges at the crossing points of the white bars is clear:

> The apparent brightness of each point on the white grid depends on the amount of black which exists in a certain area around it. If one assumes the diameter of this area to be larger than the width of the white stripes, then each point on the intersections receives in its surround less black than any other point on the white stripes; its brightness will thus be less enhanced by contrast and must therefore appear darker. (Hermann, 1870, p. 14, translation from Spillmann, 1994, p. 692)[2]

Figure 6.2 illustrates Hermann's proposal.[3]

The second feature of the illusion is that the smudges do not appear at the viewer's fixation point. If the viewer changes her point of fixation, the

[1] Contemporary discussions might frame Hermann's idea in terms of receptive field sizes. This conceptualization would be anachronistic. Sherrington (1906) is widely credited with introducing the concept of a receptive field size as referring to the area of skin that could be stimulated to elicit a scratch response. Hartline (1938) extended the concept to that area on the retina from which a response in another cell could be elicited.

[2] Note Spillmann's assumption that Hermann's "Die Erklärung" is appropriately translated as "an explanation."

[3] Note that on Hermann's account, unlike more recent accounts, the illusion is due to excess brightening of the bars away from the crossing points, rather than a darkening of the region of the crossing points. Cf., Spillmann (1994, p. 692).

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Figure 6.3 In central vision, the relevant parts of the visual system are sensitive to smaller regions so that they do not differ in their generation of simultaneous contrast.

region where the smudges appear changes. In Hermann's account, the smudges do not appear at fixed crossing points. Hermann's explanation of the absence of the illusory perception in central vision, illustrated in Figure 6.3, is that the central regions responsible for simultaneous contrast are smaller than the peripheral regions for simultaneous contrast:

> Furthermore, that darkening does not occur in fixed crossing points is explained by the assumption that, for objects that are imaged on the center of the retina, the perimeter within which the simultaneous contrast applies is smaller than for other areas. (Hermann, 1870, p. 14)

Thus, Hermann postulates individuals and activity instances that compositionally explain the illusion.

Before moving on to subsequent historical developments, let me review how various features of the theoretical framework developed in Chapters 2 through 4 describe what Hermann was doing. To begin with, a specific human's perceiving the illusion at a given time is an activity instance of an individual. Hermann believes this is explained by unspecified activity instances of unspecified retinal elements. More concretely, Hermann does not articulate the explanation in terms of, say, firings of action potentials in retinal ganglion cells (RGCs) or graded potentials in photoreceptors. This is an instance of an "individual-free" and "activity-free" explanans.

A second thing to note is the enabling role of the area to which a retinal element responds. Size figures into the explanation of both of the explananda Hermann tries to explain. Regarding the first explanandum, the size of the unspecified retinal elements – a property instance – enables it to engage in an unspecified activity instance that implements an instance of a perceived smudge when the element falls at a crossing point. By contrast, that size instance does not enable an instance of that unspecified activity

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when the retinal element falls on a horizontal or vertical bar. Regarding the second explanandum, the small size of the unspecified retinal element in central vision explains why there are no illusory smudges at the fixation point, but only in peripheral vision. So, an accurate recounting of Hermann's explanations must recognize both the activity and property instances.

Note, as a third thing, that Hermann's experiment involved presenting grids of various descriptions to humans and soliciting their verbal responses. In these experiments, there is what subjects perceive and there is what subjects say they perceive. Hermann assumes that these verbal reports often or typically indicate what subjects perceive. To use the terminology of Chapter 3, the data in this case are the human responses and the results are the human perceptions. In more recent psychological work, there is often considerable debate over the extent to which verbal reports accurately indicate what subjects perceive. There is a worry that what a subject reports is influenced not only by what the subject perceives, but also by post-perceptual processes of judgment.[4] Hermann, however, did not have those concerns.

Fourth, note that Hermann used intralevel psychophysical experiments wherein he presented a subject with a visual stimulus, then took the subject's verbal report. Based on these experiments, he postulated that unspecified individuals in the brain generate simultaneous contrast. As reviewed in Chapter 5, Hodgkin and Huxley also used intralevel experiments – manipulating axonal membrane potentials and measuring subsequent currents – as a basis for drawing inferences about ion fluxes and conductances. Hodgkin and Huxley could specify the explanans entities and activities. Hermann's inferences, however, left hypothetical entities – individuals and their activity instances – unspecified. Of course, while some of Hodgkin and Huxley's inferences did specify the hypothetical entities engaged in activity instances, that is, movements of sodium and potassium ions, some of their other inferences did not, that is, what individuals in the membrane change during changes in membrane permeability.

Finally, note the retinal activities to which Hermann alludes are not the biological bases of the *experiences* of the illusion. Those biological bases, whatever they are, are widely assumed to be cortical. Thus, I propose that Hermann thinks that the retinal activity instances compositionally explain a contributing activity to the perception of the illusion, where the

[4] The literature on this topic is so extensive that there is little point in trying to refer to any significant number of works. I will, however, refer to just one paper that is especially important: Firestone and Scholl (2014).

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perception of an illusion refers to a process that begins in the retina and ends somewhere in the cortex.

6.2 Baumgartner's Retinal Ganglion Cell Theory

Developments in the 1950s helped specify Hermann's physiological hypotheses.[5] Barlow (1953) reported the discovery of ganglion cells in the frog retina that displayed lateral inhibition.[6] In the first step in one of the relevant experiments, Barlow isolated cells that respond either to the onset or offset of a spot of light in a cell's receptive field. In the second step, Barlow showed that adding a second spot of light a small distance from the first would inhibit responses to both the onset and offset of the first spot. In the discussion of his results, Barlow proposed that, "Simultaneous contrast effects are presumably caused by an inhibitory mechanism similar to the one described; a white spot surrounded by black looks brighter (more impulses) than a white spot of the same intensity surrounded by grey, because the grey falls on the inhibitory fringe of the ganglion cells, and so inhibits their discharge (causes fewer impulses)" (Barlow, 1953, p. 85). Unlike Hermann, Barlow tied simultaneous contrast to specific activity instances, namely, electrical discharges, and to specific retina elements, namely, ganglion cells.

Kuffler (1953) provided important complementary results in experiments with cats. Simplifying somewhat, Kuffler found that some ganglion cells responded to spots of light in their receptive field centers, but were inhibited by spots of light in a surrounding annulus. These were ON-center, OFF-surround cells. In addition, he found cells with a complementary organization. The OFF-center, ON-surround cells were inhibited by spots of light in their receptive field centers but were responsive to spots of light shown in a surrounding annulus. Like Barlow, Kuffler drew attention to part of the perceptual significance of his results: "This should be advantageous in the perception of contrast" (Kuffler, 1953, p. 65). Further, he was specific about the activity instances and individuals.

In his three-paragraph paper of 1960, Baumgartner revised Hermann's account, incorporating Barlow and Kuffler's physiological work.[7] In outline, he proposed that RGCs were the retinal elements to which Hermann referred, that the firings of RGCs were the activity instances implementing a perception of the illusion, and that the sizes and response

[5] For further historical discussion, see Spillmann (2014).
[6] Later discussions describe these as "retinal ganglion cells."
[7] Baumgartner (1960).

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properties of RGCs were the enabling property instances. In other words, Baumgartner realized that RGCs and their activity and property instances filled out the details of the explanation developed by Hermann.

For the case of white bars on a black background, Baumgartner hypothesized that when an ON-center/OFF-surround cell falls at an intersection, there is more OFF-surround stimulation, thereby making for a weaker cell response and a smudge. By contrast, when an ON-center/OFF-surround cell falls along a line away from an intersection, there is less OFF-surround stimulation, thereby making for a stronger cell response and no smudge. For the case of black bars on a white background, there is a correlative story implicating OFF-center/ON-surround cells.

It is worth noting that my interpretation is based on the following translation from Baumgartner's German:

> The darkening of the light bars at the crossings is then explained by the here more pronounced edge zone inhibition, which reduces the activation of the on-neurons in comparison to the other bar sections. Conversely, the lightening of the dark bars in the crossing region is to be understood by the lower activation of the off-neurons from the edge zone since the positive dark impression correlates with the frequency of the dark-activated neurons. (Baumgartner, 1960, p. 22)[8]

In adopting this translation, I assume that the German "erklärt" is correctly translated as "is explained by" and that "verstehen" is correctly translated as "is to be understood." Further, I assume that Baumgartner's choice between "erklärt" and "verstehen," although they differ in meaning, does not reflect any serious scientific difference. Instead, they are for Baumgartner's purposes, merely different stylistic choices. I do not presuppose that these interpretations are completely obvious, but they are plausible.

Like Hermann, Baumgartner supposes that he can explain why the smudges do not appear in central vision in terms of the sizes of the receptive fields of retinal ganglion cells. Baumgartner's explanation is essentially the same as Hermann's explanation, illustrated in Figure 6.2. The additional ON-center/OFF-surround structure of RGCs leaves Hermann's account unchanged: both the ON-center and OFF-surround of RGCs in central vision fall within the white crossing point, so there is no OFF-surround contribution to darkening.

One of the philosophically interesting features of Baumgartner's discussion lies in his final paragraph. He reasons that, if the illusion is strongest

[8] Many thanks to Beate Krickel for reviewing this translation.

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when the size of the ON-center matches the angular width of the intersecting bars, then this provides an estimate of the ON-center diameter of >25 μ. What is interesting is that this implies that Baumgartner thought that RGCs produced the illusory perception. If RGCs did not generate the phenomenon, then why would the viewing of the grid be relevant to RGC receptive field size? Although one might reasonably conjecture that Hermann thought that the individual-free explanans he proposed in 1870 was correct, there is no firm textual basis. However, Baumgartner adds some brief comments that commit him to RGCs being involved in the Hermann grid illusion. That further implies that he thinks that singular compositional abduction provides evidence supporting the RGC hypothesis.

6.3 Development of the Retinal Ganglion Cell Theory

Baumgartner's paper did not report on experiments he performed, so he was not strictly speaking interpreting his experimental work. Spillmann (1971), however, treats the RGC hypothesis in a properly experimental context. For the sake of brevity, I will focus on Spillmann's discussion of ON-center/OFF-surround cells, and his experiments to estimate their receptive field sizes. As with Baumgartner, the method of estimating sizes presupposes that, in fact, retinal ganglion cells are part of the neurophysiological basis of the illusory perception.

In brief, Spillmann hypothesized that a cell will produce a smudge of maximal intensity if it is precisely sized and centered at a standard crossing point on the grid. This is Baumgartner's assumption in the final paragraph of his paper. It is the configuration of the second cell from the right in Figure 6.4 below. The two cells on the right would have this same maximal intensity, since the portion of the bars outside of the cell's receptive field would not influence its firing. Decreasing the size of the bars outside the ON-center and detecting just noticeable differences in the intensity of the illusion would, therefore, provide an estimate of the entire receptive field. In contrast to this, the two cells on the left-hand side of the figure would produce weaker smudges, because they have less OFF-surround stimulation. Of the two cells on the left, the cell farthest to the left would produce a weaker smudge than the cell second from the left. All of this was hypothetical reasoning.

Spillmann checked the consequences of his hypotheses in his "Series A" experiments. In these experiments, subjects first view the standard Hermann grid to learn to recognize the illusion. Then, modified grids, such as the one in Figure 6.5, were presented to them. Eight standard

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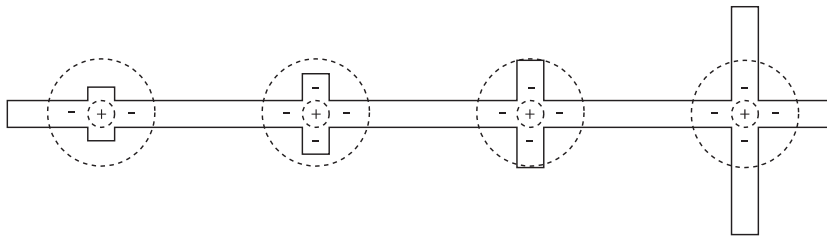


Figure 6.4 Illustration of Spillmann's hypothetical thinking regarding the Hermann grid illusion. A RGC on the far right would produce the maximal amount of darkening. So, would the RGC second from the right since the portion of the vertical bar that falls outside the cell's receptive field would not influence its response. The two RGCs on the left, by contrast, would produce submaximal responses, with the cell on the far left producing a weaker response than the cell second from the left. Redrawn from Spillmann (1971, p. 284, figure 2b).

intersections were along the sides, whereas the central regions had eight experimental bars symmetrically shortened to various lengths. (Note that one of the experimental bars was a "null bar," with no vertical length. This is in the upper middle left of Figure 6.5.) Subjects were first asked to fixate experimental bars to see if a smudge was present.[9] If so, then subjects were asked to compare the experimental bar with a nearby standard intersection. The comparisons were either "weaker," "equal," or "stronger." Seven college undergraduates with 20/20 uncorrected vision or better, with no significant astigmatism, were participants.

Results from the Series A experiment are shown in Figure 6.6. The leftmost curve with squares plots the probability of a subject reporting no effect (the ordinate) versus the length of the experimental bar in arcmin (the abscissa). Experimental bars shorter than about 11 arcmin have less than a 50% chance of inducing a reported effect. The middle curve with circles plots the probability of a subject reporting an experimental effect that is weaker than the standard effect. The right curve plots the probability of a subject reporting an experimental effect that is the same as the standard effect. Thus, experimental bars longer than about 19 arcmin are more than 50% likely to be indistinguishable from the standard bars. No experimental bars were reported to produce a stronger effect than a standard bar. There were no differences between horizontal experimental bars and vertical experimental bars. Spillmann interprets the 19 arcmin

[9] It is unclear from Spillmann's discussion how fixating an intersection was consistent with the illusion standardly appearing in the visual periphery.

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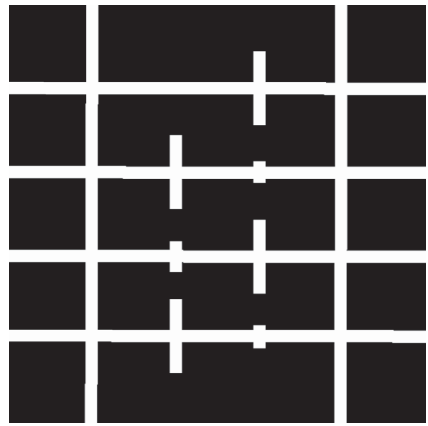


Figure 6.5 Stimuli from Spillmann's "Series A" experiments. Eight "standard" intersections are on the right and left columns. "Experimental" intersections with shortened bars are shown in the middle. Subjects compared "experimental" intersections with their nearest "standard" intersections. Another image using horizontal bars was also used. Redrawn from Spillmann (1971, p. 284, figure 2a).

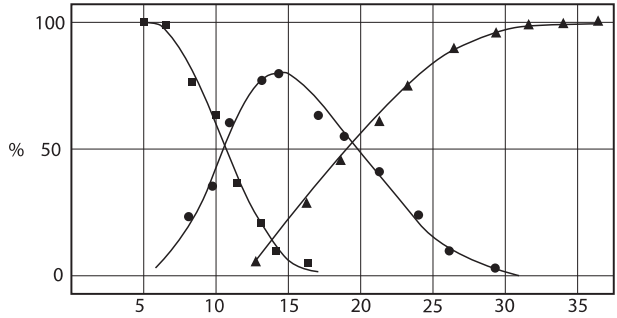


Figure 6.6 Percentage distribution of responses for series A as a function of bar length (in min of arc). The first intersection of the curves at the 50% level (squares and circles) indicates the minimal angular length of a pair of bar extensions necessary to produce a just noticeable darkening effect. The second intersection at the 50% level (circles and triangles) marks the threshold at which the grid illusion reaches a maximum. This length is considered equivalent to the diameter of a foveal perceptive field. Redrawn from Spillman (1971, p. 286. figure 3).

figure as an estimate of the receptive field size, matching the hypothetical picture of the right half of Figure 6.4.

Notice, to begin with, the overarching structure of Spillmann's argumentation. He begins with the hypothesis that the biological basis of the

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grid illusion lies in the activity of RGCs. Using Figure 6.4, he reasons that if this is so, then as vertical bars increase in length there will be a point at which darkening first manifests itself. Further, if the vertical bars increase in length even more, then they will increase up to a value at which the vertical bars reach the full extent of the ON-center, OFF-surround receptive field and, therefore, a maximal intensity of the illusory smudge. He then compares the consequences of this hypothesis against an experimental determination. He finds that there is indeed a point at which the increasing length of the vertical bars leads to a maximal darkening. The dependencies outlined by the RGC hypothesis are found to obtain. The RGC hypothesis explains why there is a maximum bar length and thereby enables Spillmann to estimate the total receptive field to be about 19 arcmin. Each measurement corresponds to an instance of a singular compositional abductive inference. Here again is an instance of hypothetical reasoning that I take to be better understood as relying on abductive confirmation than HD confirmation.

Next, consider the structure of the experiment more closely. Each data point represents a judgment of "weaker," "equal," or "stronger." (Again, in the actual experiment, no judgments were "stronger.") Each datum is a verbal report. What is to be reported is a comparison between two perceptions. Let S Ψ-ing be an instance of a subject S's perception when S fixates a standard intersection, such as the one in the lower right-hand corner of Figure 6.5. Let x_i ϕ_i-ing be an instance of the firing activity of a single retinal ganglion cell when it is centered on that standard intersection. Let S Ψ*-ing be an instance of a subject S's perceiving when S fixates the short experimental intersection on lower right-hand corner of Figure 6.5. Let x_i ϕ_i*-ing be an instance of the firing activity of a retinal ganglion cell when it is centered on the short experimental intersection in the lower right-hand corner of Figure 6.5. In this experiment, an individual S is asked to make multiple comparisons of S Ψ-ing versus S Ψ*-ing.[10]

Notice, in addition, that each datum – each judgment of "weaker," "equal," or "stronger" – is a spatiotemporal particular based on a data target – an introspective comparison of two further spatiotemporal particulars, S Ψ-ing and S Ψ*-ing. S Ψ-ing and S Ψ*-ing are distinct activity instances of S; they are distinct results. One is, as it might be, an instance

[10] Note that, in this experiment, Spillmann does not have an explanation of S Ψ-ing in terms of x_i ϕ_i-ing or of S Ψ*-ing in terms of x_i ϕ_i*-ing, but only of S Ψ-ing differing from S Ψ*-ing in terms of x_i ϕ_i-ing and x_i ϕ_i*-ing differing. These explanations are distinct from other controlled experiment explanations, as discussed in Chapter 3.

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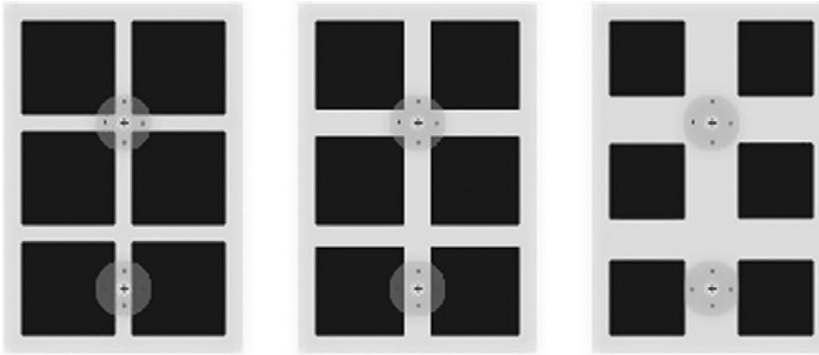


Figure 6.7 The Hermann grid effect weakens and finally disappears when the retinal image of the intersection is either too small or too large with respect to the perceptive field center. The reduction of the effect with greater than optimal bar widths is attributed to the decreasing difference in lateral inhibition between perceptive field centers illuminated by bar or intersection, respectively.

of a perception of a dark smudge, whereas the other is an instance of the perception of a light smudge. Further, Spillmann assumes that S Ψ-ing is singularly compositionally explained by x_i ϕ_i-ing, whereas S Ψ*-ing is singularly compositionally explained by x_i ϕ_i*-ing. Spillmann can, of course, generalize from these instances, concluding that the perception of smudges is implemented by the firings of RGCs, but those are generalizations from the singular compositional explanations.

Consider now a second experiment that again illustrates a role for singular compositional abductive inference. Spillmann reasons that, if the grid illusion is due to RGCs, then there should be a bar width at which the smudges are most intense with the intensity decreasing at greater bar widths (see Figure 6.7). To test this, he had participants view his "Series A" grids moving the participants nearer or farther from the grids while seated in a roller chair. For six student subjects, there was an ascending and a descending threshold ($n = 12$). Pooled and averaged, the results yield an average value of 18.7 arcmin for the entire receptive field. As predicted by the RGC theory, there was indeed a maximum bar size for the illusion.

Notice that, in this argumentation, there is hypothetical reasoning and it is used to confirm the RGC hypothesis. If the grid illusion were due to RGCs, then there should be a maximal bar size. There is a maximal bar size, which is explained by the RGCs generating the illusion. Further, each of the twelve subject judgments – each verbal report – is a datum aimed at

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a data target regarding the perception of a smudge. In each of the twelve cases, the thought is that at a given distance from the screen on which the grids are projected, the RGCs do not generate an illusion. Spillmann then calculates the size of the putative receptive field for each case, and then calculates an average. There are, thus, two inferences here. First, there is the abductive inference regarding the receptive field size for a particular instance, then there is the computation of the average from the abductively inferred receptive field sizes.

6.4 Challenges to the Retinal Ganglion Cell Hypothesis

In this section, I will review five experiments that I take to illustrate scientists using compositional abduction in attempts to disconfirm the RGC hypothesis. Two are from Wolfe (1984) and three are from Schiller and Carvey (2005). I have selected these arguments because they are relatively accessible. Further, I have chosen arguments from different papers to show that using compositional abduction for disconfirmation in experimental contexts is not idiosyncratic to one scientist.[11] I think the picture of singular compositional abduction from Chapter 4 fits these examples.

Wolfe (1984) provides two simple experiments illustrating abductive disconfirmation of the RGC hypothesis. He notes that the RGC hypothesis focuses exclusively on local factors, roughly speaking, what falls within the scope of a single receptive field. He reasons that, were this true, then the global structure of the display should not influence the perception of the illusion. The disconfirmation arises when the global structure of the display is found to influence the perception.

For the first experiment, Wolfe reasons that "If the Hermann grid illusion could be explained entirely on the basis of the local activity of concentric receptive fields, then the effect should be equally strong with one or many intersections" (Wolfe, 1984, p. 34). Clearly, Wolfe is reasoning hypothetically. Therefore, the experiment is intended to show

[11] There are other examples of compositional abductive disconfirmation in Schiller and Carvey (2005). Further, Spillmann (1971, pp. 294–295) uses compositional abduction to try to disconfirm the hypothesis that eye movements implement the grid illusion. Schiller and Carvey (2005, p. 1386) uses compositional abduction to disconfirm the hypothesis that the grid illusion is implemented by rod/cone interactions. In the interests of full disclosure, it is unclear to me what philosophical theory fits Schiller and Carvey's seventh argument against the RGC hypothesis. Their argument is that the spatial arrangement of retinal ganglion cell receptive fields is not what has been assumed by the RGC theory. See Schiller and Carvey (2005, p. 1382).

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Table 6.1 *Parameters of the thirteen grids in Wolfe's first experiment*

Grid	Number of intersections	Length of block (deg)	Length of grid (deg)
1	1	1.6	4.0
2	4	1.6	6.0
3	9	1.6	8.0
4	16	1.6	9.8
5	25	1.6	11.6
6	36	1.6	13.5
7	1	1.2	3.4
8	9	1.2	6.0
9	36	1.2	11.0
10	1	2.3	5.6
11	9	2.3	10.7
12	1	3.6	8.0
13	4	3.6	11.6

that the effect is not equally strong with one or many intersections. To do this, Wolfe used grids that differ in the number of intersections, the size of the blocks, and the overall length of the grid, as shown in Table 6.1. Wolfe also used both black-on-white grids and white-on-black grids. The ten subjects in the experiment were taught a rating scale of 1–9, wherein 7 was indexed to a grid with 36 intersections (grid 6 in Table 6.1). 1 represents no illusion and 8–9 represent an illusion stronger than the reference grid 7. Wolfe found a strong effect of number of intersections.

For the second experiment, Wolfe hypothetically reasoned, "If each intersection produces the same illusion regardless of its surround, then 25 irregularly placed intersections should produce the same magnitude of illusion as a 5 x 5 square grid" (Wolfe, 1984, p. 37). Wolfe disconfirmed the RGC hypothesis by showing that stimuli consisting of irregularly placed intersections – essentially fields of randomly placed "+"s – produced a weaker illusion than do stimuli consisting of standard grids. For this study, only black "+"s on a white field were tested. Stimuli with 1, 4, 9, 16, and 25 intersections arranged irregularly were compared with standard grids having 1, 4, 9, 16, 25, and 36 intersections. The results represented in Figure 6.8 show that the regular organization of the standard grid stimuli has an effect, but also that there is a weak effect due to the number of intersections. (Wolfe does not provide a statistical analysis.)

Schiller and Carvey (2005) provides several reasons that they take to challenge the hypothesis that the perception of the Hermann grid illusion

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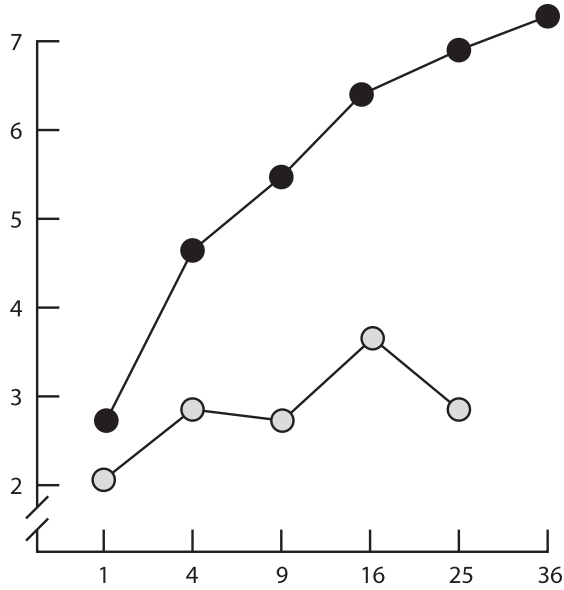


Figure 6.8 The magnitude of the illusion (abscissa) as a function of the number of regularly and irregularly placed intersections (ordintate). Redrawn from Wolfe (1984, p. 38, figure 5).

is generated by RGCs, but support the hypothesis that the illusion is generated, at least in part, by so-called S1 cells in area V1. Most of these reasons involve compositional abduction. Schiller and Carvey cite features of the illusion that they claim cannot be explained by the RGC theory but can be explained by their S1 theory.

Before reviewing the abductive arguments, I should comment that Schiller and Carvey note that their paper does not report on experiments. They, instead, invite the reader to demonstrate the features of the illusion for herself: "Rather than reporting on experiments conducted in a small population of subjects, this paper consists of a series of demonstrations that allow the reader to serve as subject as well as judge. The demonstrations are compelling and we are confident they will convince the readers of the validity of the claims made" (Schiller & Carvey, 2005, p. 1376). Schiller and Carvey, along with the editors of the journal, believe that experiments are unnecessary. This work is, therefore, strictly speaking, not a matter of the interpretation of experimental results, but it is clear how the interpretation of the demonstrations would carry over to the interpretation of *bona fide* experimental results.

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The lack of experimental results renders the Schiller and Carvey argumentation less than a perfect study for my purposes. Nevertheless, Schiller and Carvey (2005) does have the attractive feature that Schiller and Carvey are generally explicit in their appeals to explanatory considerations in support or criticism of a theory. For example, there is a section of the paper entitled "Why the retinal ganglion cell theory is untenable" and it begins with the contention that: "the retinal ganglion cell theory cannot appropriately explain the Hermann grid illusion" (Schiller & Carvey, 2005, p. 1377). Although such explicit commitments are not always forthcoming, it is convenient when there is a consilience of scientific and philosophical accounts.

Consider, now, three features of Hermann grid stimuli that Schiller and Carvey think challenge the RGC hypothesis but support a rival hypothesis. Here, I review only the first three of six features that do this work for Schiller and Carvey. The first three are the simplest and should suffice to make the point that Schiller and Carvey use abductive confirmation and disconfirmation. The interested reader can consult Schiller and Carvey (2005) for the remaining examples.

The illusion is perceived over a large range of sizes.[12] As Schiller and Carvey note, the reader might verify this feature of the illusion by viewing a familiar version of the illusion from different distances.[13] An experiment along these lines would move the viewer or the grid, and then measure the perceiver's perceptual response relying on the perceiver's verbal report. This would be an intralevel experiment. The RGC theory cannot explain the results of this experiment, since RGCs have fixed receptive field sizes. By contrast, Schiller and Carvey's rival hypothesis is that the illusion is generated by S1, simple cells, in area V1. These cells have much more variable receptive field sizes, which partly explains why the illusion is perceived over a range of sizes.

Note that the diversity of receptive field sizes is, for Schiller and Carvey, only part of the S1 theory's explanation of the illusion. In the first pass through the S1 theory's explanation, they write, "The fact that receptive field coverage is not limited to only one size can explain why, for a given retinal eccentricity, the illusion persists when the size of the grid is varied" (Schiller & Carvey, 2005, p. 1389). In a later commentary they write,

> [I]t has been shown that the illusion is effective over a range of sizes which is problematic for the retinal ganglion cell theory. The S1 theory is less affected by this observation for the following reasons: (I) the receptive fields

[12] The italicized headings here are borrowed from Schiller and Carvey (2005).
[13] Schiller and Carvey (2005, p. 1377).

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> of cortical cells are larger and more variable in size . . . (ii) their responses are largely controlled by the orientation of edges . . . and (iii) responses in many cells summate as the length of the line segment is extended. (Schiller & Carvey, 2005, p. 1391)

These refinements do not change the central point that Shiller and Carvey think there is reason to believe in the S1 theory, namely, that it explains the variability in the size of the grids that stimulate the Hermann grid illusion.

The illusion is reduced when the grid is rotated by 45°. The reader might verify this observation by simply viewing the standard grid and then rotating it by 45°, but Schiller and Carvey refer to various experiments in the literature that support this view. They especially support a quantitative study of this phenomenon in De Lafuente and Ruiz (2004). The problem for the RGC theory is that the receptive fields of RGCs are radially symmetric, so the illusion should be unchanged by rotation of the grid. In contrast to RGCs, S1 cells are orientation sensitive. They are, one might say, oriented line detectors. Further, there appear to be more S1 cells dedicated to representing horizontal and vertical lines than there are to presenting diagonal/oblique lines. Thus, the S1 hypothesis can explain the weakening of the illusion in terms of fewer S1 cells responding to the grid.

The illusion can be reduced or eliminated by manipulations that do not alter the antagonistic center/surround activation of retinal ganglion cells. Here, Schiller and Carvey refer to a wide range of phenomena. For one thing, the illusion is reduced if the black squares forming the background are replaced by black parallelograms with four equal-length sides. As with the last problem, the problem for the RGC theory here is that the receptive fields of RGCs are radially symmetric, so the illusion should be unchanged by the angles of the white bars at the intersections. By contrast, the S1 theory can explain the weakening in terms of the fewer S1 cells representing the diagonals.[14]

6.5 Confirmation by Singular Interlevel Abduction

The cornerstone of my methodology is to carefully examine scientific reasoning regarding compositional hypotheses as presented in the primary experimental literature. Fidelity to actual science is the core desideratum. There are, however, other desiderata one might have. Many philosophers

[14] Surprisingly, Schiller and Carvey refer to other features of other grid variations that are not explained by the RGC theory, but for which they do not provide an S1 explanation.

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of science seek a universal account. In the context of the confirmation of compositional hypotheses, this might be an account that applies to all instances of scientific reasoning in support of compositional hypotheses. In Chapter 1, I rejected the goal of such a universal account. In my reading of the scientific literature, there is such a diversity of things that are treated as explanations and used for abductive inference that, at this stage of philosophical investigation, it is unlikely that there will be a universal account. Here I will illustrate the scientific confirmation of a compositional hypothesis that does not use singular compositional abduction. The example relies on singular interlevel abduction.

Schepelmann et al. (1967) presented cats with Hermann grid stimuli and recorded responses from single cells. Given the RGC hypothesis, they anticipated finding cells that respond more strongly to the onset of lights on either horizontal or vertical bars, but more weakly to the onset of lights at the intersections of grids. Moreover, the findings were as expected. Here is Spillmann's commentary on the experiment:

> (Schepelmann et al., 1967) tested the receptive-field explanation of the Hermann grid illusion by recording impulses from individual fibers in the optic nerve and from single cells in the lateral geniculate nucleus and visual cortex of the cat. They found a neuronal response pattern consistent with the illusion for cells at all three levels, including simple cells. . . . The firing rate is about the same for the vertical and horizontal bars, but is much reduced when both bars are presented together, intersecting each other. This reduction of the firing rate might be considered a neurophysiological correlate of the perceived darkening; it is consistent with Baumgartner's receptive field explanation of the Hermann grid illusion. (Spillmann, 1994, p. 694)[15]

Notice that, in this test of the RGC theory, Schepelmann, Aschayeri, and Baumgartner intervene on cats, then measure responses from cells in the retina, lateral geniculate nucleus, and area 17. This is a top–down experiment, unlike the many intralevel experiments throughout Chapters 5 and 6. Such experiments will not be understood as are the previous intralevel experiments interpreted as compositional abduction.

Consider, once again, the first experiment from Spillmann (1971). (The second would work just as well.) In the first experiment, Spillmann found that when the bars are shortened, the illusion is weakened. This is a psychophysical result. It concerns the connection between a physical stimulus to an organism and the organism's perception. This result provokes an intralevel explanation-seeking why-question: "Why is the illusion

[15] Cf., Spillmann (2014, p. 1156).

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weakened when the bars are shortened?" Spillmann's answer: The illusion is implemented by RGCs with ON-Center, OFF-surround receptive fields, so that as the cross bars decrease in size, they decrease their influence on the OFF-surround. Compare this with experiment in Schepelmann et al. (1967). In this experiment, Schepelmann et al. presented visual stimuli to cats, and then measured cellular responses. The result was not a standard psychophysical result; the experiment was not a standard psychophysical experiment. It did not manipulate a cat and then measure the cat's response; it manipulated a cat and then measured cellular responses. In other words, the Schepelmann et al. (1967) experiments were top–down experiments. The results of the Schepelmann et al. (1967) experiments, thus, provoke an interlevel explanation-seeking why-question: "Why do RGC cells respond more strongly to horizontal or vertical bars than to intersections?" Spillmann's answer: The illusion is implemented by RGCs with ON-Center, OFF-surround receptive fields, so that stimuli that produce the illusion also stimulate RGCs.

Both of the answers to the why-questions – both explanations – invoke the hypothesis that the illusion is implemented by RGCs with ON-Center, OFF-surround receptive fields. Both of these explanations are explanations of experimental results. Yet, in the former case, the explanandum is an individual engaged in an activity instance, whereas, in the latter case, the explanandum is of an interlevel connection. Thus, insofar as one types abductive inferences by reference to their embedded explanations, we have reason to draw a distinction between compositional abductive inferences and interlevel abductive inferences.

6.6 Summary

This case study illustrated many of the same points as made in the case study on resting and action potentials. In the interpretation of the results of controlled experiments in the primary experimental literature, scientists often use singular compositional abduction as a basis for confirmation and disconfirmation. One feature not found in the Hermann grid illusion study is the explanation of rates. Another, more significant, innovation from this case study is "singular interlevel abductive inference." These are abductive inferences based on an interlevel explanation. In the top–down experiment reviewed here, there was an interlevel explanation of an experimental result in which the presentation of a Hermann grid stimulus resulted in the increased firing of a retinal ganglion cell. I shall return to singular interlevel abductive inferences in Chapter 10.

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