Synesthetic perception as continuous with ordinary perception, or: We're all synesthetes now

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Rather than displaying merely some odd, fortuitous associations, these universal synesthetic experiences reflect important cognitive properties that in several respects are common to normal people as well as to synesthetes (Marks, 1975, 303).

Abstract

How we understand the relationship between synesthetic and normal perception depends both on how we conceive of synesthetic perception and normal perception. In this paper I'll argue that, given what we know about both, the most plausible view is that synesthesia is not a fundamentally distinct, pathological outlier relative to normal perception; rather, it is best understood as continuous with capacities present in normal perception.

I'll argue for this conclusion in three ways. First, I'll argue that the feature at the core of our understanding of synesthesia — a form of informational integration between normally unconnected psychological systems — is also ubiquitous in normal perception. Second, I'll consider similarities and differences between synesthesia and informational integration in normal perception. I'll review evidence to the effect that there are striking, detailed, and otherwise unexpected similarities between the two forms of informational integration, and I'll argue that the evidence some have taken to reveal significant qualitative differences between informational integration in synesthetes and normal perceivers is far less decisive than it might first appear. Finally, I'll show how an understanding of synesthesia as continuous with normal perceptual capacities correctly predicts the otherwise surprising result that synesthetes perform better than non-synesthetes in certain perceptual tasks that don't implicate synesthetic perception. The upshot, I'll suggest, is that synesthetic perception is usefully viewed as much closer to non-synesthetic perception (a fortiori, less clearly pathological) than standard views allow.

One of the central outstanding puzzles about synesthesia, and one that is at least partly to blame for the recent surge in attention given to the condition

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by philosophers and psychologists, is that of understanding the relationship between synesthetic perception and normal perception. Of course, the answer we give to this puzzle will depend on how we conceive of both synesthesia and normal perception. In this paper I'll argue that, given what we know about both, the most plausible view is that synesthesia is not a fundamentally distinct, pathological outlier relative to normal perception; rather, it is best understood as continuous with capacities present in normal perception.

I'll argue for this conclusion in three ways. First, I'll argue that the feature at the very heart of our understanding of synesthesia — informational integration between psychological systems — is also ubiquitous in normal perception (§1). Second, I'll consider similarities and differences between synesthesia and informational integration in normal perception (§2). I'll review evidence to the effect that there are striking, detailed, and otherwise unexpected similarities between the two forms of informational integration (§2.1), and I'll argue that the evidence some have taken to reveal significant qualitative differences between informational integration in synesthetes and normal perceivers is far less decisive than it might first appear (§2.2). Finally, I'll show how an understanding of synesthesia as continuous with normal perceptual capacities correctly predicts the otherwise surprising result that synesthetes perform better than non-synesthetes in certain perceptual tasks that don't implicate synesthetic perception (§3). The upshot, I'll suggest, is that synesthetic perception is usefully viewed as much closer to non-synesthetic perception (a fortiori, less clearly pathological) than standard views allow.

1 Informational integration, synesthetic and otherwise

My first line of argument for construing synesthesia as continuous with normal perception rests on a piece of conceptual analysis: my claim is that the distinctive feature at the core of synesthesia is in fact present, ubiquitously, in normal perception. To make this case I'll first attempt to distill out a minimal essence of what is distinctive about synesthesia (§1.1); then I'll argue that that same feature shows up surprisingly often in normal perception, so long as the latter is seen aright (§1.2), and that this fact points us in the direction of thinking of synesthetic and normal perception as species of a common kind (§1.3).

1.1 Synesthesia

There is much about synesthesia that is understood poorly or not at all. Among other controversies, there is debate over the classification and definition of the condition (e.g., Cytowic, 2001; Hubbard, 2007; Macpherson, 2007), the diversity of its forms (Day, 2005),[1] its unity as a psychological kind (Ramachandran

[1]Sean Day lists "more than 65" types of synesthesia, individuated by inducer/concurrent pairs, at his web site (`http://www.daysyn.com/Types-of-Syn.html`).

and Hubbard, 2001; Dixon *et al.*, 2004; Simner, 2012),[2] and whether it is inherited or acquired (Armel and Ramachandran, 1999; Beauchamp and Ro, 2008; Harrison and Baron-Cohen, 1995; Cohen Kadosh *et al.*, 2009; Asher *et al.*, 2009). Similarly, there is controversy over whether the experience of an A-B synesthete (one whose perceptual encounters with A cause an experience that is associated in normals with perception of B) is like that of a normal subject but with an added, synesthetic layer of normal experience (as it were, a normal A-type experience conjoined with a normal B-type experience), or whether her synesthetic experience is simply alien/incomparable to the experiential inventory of normals. There is controversy about the implications synesthesia has for the individuation of the senses (Keeley, 2013) and philosophical views such as functionalism (Gray *et al.*, 1997, 2002; Macpherson, 2007), representationalism (Wager, 1999, 2001; Alter, 2006; Gray, 2001b; Rosenberg, 2004), and modularity (Baron-Cohen *et al.*, 1993; Segal, 1997; Gray, 2001a).[3]

Despite all this controversy, there is at least one idea about synesthesia that seems uncontroversial: on more or less all accounts, synesthesia involves the presence of (abnormal) influence between systems that, in ordinary circumstances, represent distinct features. That is, what makes a grapheme-color synesthete's experience (more generally, an A-B synesthete's experience) notable is that, in her, the system that in ordinary circumstances represents grapheme identity (/A) activates or mediates representations in the system that, in, ordinary circumstances, represent color (/B). Hence occurrences of A in such a subject (the "trigger"/"inducer") mediate representations of B (the "concurrent"). Moreover, notice that the link between the A system and the B system in synesthetic perception is not merely causal: it is not only that the activity of the A system initiates or triggers activity in the B system, but that the resulting particular state of (hence, information carried by) the B system counterfactually/informationally depends on the particular state of (hence, information carried by) the A system that does the triggering. Thus, in grapheme-color synesthesia, for example, it is not only that the activity of the grapheme-representation system causes activity in the color-representation system (though that is true). Crucially, and in addition, *which* color is synesthetically represented by the color system depends counterfactually/informationally on which grapheme is represented in the grapheme-representation system. Consequently, it makes sense to describe such cases by saying that the activity of the B system (unusually) draws on information

[2]Ramachandran and Hubbard (2001) distinguish between "lower" synesthetes, in whom the trigger is more closely linked to specific sensory features (e.g., in grapheme-color synesthesia, graphemes trigger the color reaction only when presented in particular fonts) and "higher" synesthetes, in whom the trigger seems less tied to particular perceived properties (thus, e.g., unusual fonts or Roman numerals will bring about the concurrent color representation). Dixon *et al.* (2004) mark a separate distinction between "projector" synesthetes, who experience their concurrents as located in space, and "associator" synesthetes, who do not.

[3]For a useful overview of these and other controversies about synesthesia, see Auvray and Deroy (2013).

represented in the A system — that there is here a kind of cross-talk, or informational integration between the A system and the B system.[4]

Now, saying this much leaves a cornucopia of questions unanswered. Perhaps most significantly, it presupposes some method for individuating psychological systems and identifying them with ordinary content-types. It also leaves plenty of room for disagreement about the nature of the causal and informational connections between the systems, and just what systems (only perceptual systems? mid-level perceptual systems? cognitive systems?) will, when joined in the relevant way, count as synesthetically linked. And it leaves open all of the controversial issues gestured at in the beginning of this section. But this far-reaching agnosticism is just the point: the idea that synesthesia involves integration between normally unconnected psychological systems constitutes an island of consensus in a sea of controversy about the condition. And it has, I suggest, a good claim to the status of essential core of our understanding of what synesthesia amounts to.

This idea is present in the Greek etymological roots of the term: *syn-* (joining), *-aesthesis* (sensation). It is reflected in the standard characterization of the condition as a merging/mixing/union/unity of the senses,[5] And it shows up in some form in all of the proposed theoretical definitions and glosses. Thus, for example, Marks (1978, 8) defines synesthesia as "the transposition of sensory images or sensory attributes from one modality to another" (cf. Marks, 1975, 303). Harrison and Baron-Cohen (1997) "define synaesethesia as occurring when stimulation of one sensory modality automatically triggers a perception in a second modality, in the absence of any direct stimulation to this second modality" (3). Harrison (2001) describes the condition as "implying the

[4] Two remarks about the notion of informational integration at work are in order. (Thanks here to Matthew Fulkerson for discussion.)

First, the term 'informational integration' shouldn't be taken to imply that the states of the A and B systems between which there is an integration carry information about any single common distal feature type. Rather, the suggestion is that there is a causal interaction between two states that carry information, despite their carrying information about different feature types. (Thus, for example, in the case of grapheme-color synesthesia, the interaction obtains between a first state that carries information about distal grapheme form and a second state that carries information about distal color.)

Second, we shouldn't assume that the way the integration works is that there will always be a (non-synesthetically induced) B representation prior to the interaction, such that the integration consists in a modification of that prior B-representation in a way that depends on the A-representation. The point is only that, whether there is a B-representation prior to the synesthetic interaction or not, the resulting state of the B-representing system is counterfactually/informationally dependent on the information represented in the A-system. In this sense, the B system (unusually) draws on information represented in the A system, so there is no informational firewall between the two. (That said, there do appear to be cases where there is a prior B-representation. For example, a grapheme-color synesthete who synesthetically represents the grapheme 'L' as green will typically also non-synesthetically perceive the black color of the ink in which that grapheme is printed. (This point explains the possibility of Stroop-like interference between synesthetic and non-synesthetic representations — now a common diagnostic for synesthesia (Dixon *et al.*, 2000; Mattingley *et al.*, 2001; Mills *et al.*, 1999) that, on its face, appears to be some kind of interesting computational combination between independently generated A and B representations.)

[5] Such phrases are used as titles or subtitles by e.g., Marks (1978); Cytowic (2001); Ward (2008).

experience of two or more sensations occurring together" (3). Cytowic (2001) offers the idea of a "sensory blending" (2). According to Ramachandran and Hubbard (2001),"Synaesthesia is a curious condition in which an otherwise normal person experiences sensations in one modality when a second modality is stimulated" (4). Similarly, Gray *et al.* (2002) write that "Synaesthesia is a condition in which, in otherwise normal individuals, stimulation in one sensory modality reliably elicits the report of a sensation in another" (5).[6] A more complicated expression of the idea comes out in Macpherson's definition:

> Synaesthesia is a condition in which either:
> (i) an experience in one sensory modality, or
> (ii) an experience not in a sensory modality, such as an experience of emotion, or
> (iii) an imagining or thought of what is so experienced, or
> (iv) a mental state outlined in either (i)-(iii), together with recognition of what the mental state represents is either a sufficient automatic cause of, or has a common sufficient automatic cause (lying within the central nervous system of the subject) with, an experience or element of experience that is associated with some sensory modality and is distinct from (i).
>
> This synaesthetic experience or element of experience can be associated with the same or a different sensory modality from that which may be ordinarily associated with the mental state in (i)-(iv) (Macpherson, 2007, 70).[7]

Without meaning to downplay or ignore the important and interesting differences between these competing definitions, I want to make the simple point that they are all, appropriately, agreeing on the central idea about synesthesia with which we started. Namely, they are agreeing (despite

[6]This formulation puts more weight on the report of the concurrent, per se, than is probably wanted; surely the report is only instrumentally useful to the extent it serves as evidence of the real item of interest — the concurrent sensation itself. If so, an improved version would define synesthesia as a condition in which, in otherwise normal individuals stimulation in a first sensory modality reliably elicits a sensation in another.

[7]Note that Macpherson's definition (unlike the others quoted) does not restrict attention to associations between specifically sensory representations. Among other benefits, the absence of this restriction leaves Macpherson's definition in a better position than competitors to accommodate the "higher" synesthetes of Ramachandran and Hubbard (2001), in whose synesthetic experience the role of sensory or perceptual representation is at best incidental. This seems like an attractive feature of her proposal.

I am less sympathetic to another of the selling points Macpherson advertises: she points out that, by restricting attention to *sufficient* causes in clause (iv), her proposed definition respects her intuition that there is a difference in kind between synesthesia and cases of crossmodal illusion (e.g., the McGurk effect) in normal perception Macpherson (cf. 2007, 70–71). Of course, it is one of the morals of the present paper to question just this intuition (hence whether respecting it is a benefit of a proposed definition). However, whatever one thinks about the status of the disputed intuition at the end of the day, the point I'm making in the main text stands: Macpherson's definition, just like the simpler proposals considered above, makes central the idea that synesthesia involves abnormal causal influence between systems that, in ordinary circumstances, represent distinct features.

their differences) that the condition crucially involves the activation and informational mediation by a system that ordinarily represents a first type of information of a system that ordinarily represents a second type of information.

There is an obvious diagnosis of the convergence on this idea by so many different theoretical proposals: viz., that the idea genuinely captures what lies at the heart of our understanding of synesthesia. At any rate, I propose that we adopt this view, and carry out our comparison between synesthesia and normal perception by (at least in part) asking whether that core idea distinguishes synesthesia from normal perception. This will be the task of §1.2.

1.2 Normal perception

Needless to say, the view we take about the relationship between synesthetic and normal perception will depend not only on how we are thinking about synesthesia but also on our understanding of normal perception. This matters because there are ways of thinking of normal perception in currency that make the informational integration characteristic of synesthetic perception look more exceptional than I believe it is. I want to argue that, on the contrary, information integration is rife in normal perception. And this, I'll suggest, should give us an initial reason to take seriously the hypothesis that synesthetic perception is continuous with non-synesthetic perception.[8]

We can begin to address the issue of informational integration in normal perception by asking whether and to what extent the individual perceptual mechanisms extracting particular distal features in normal perception — e.g., shape, color, form, and motion (in vision); pitch, loudness, and timbre (in audition) — are mutually informationally encapsulated.[9]

One logically possible answer to this question — call it the *dedicated feature extraction view* — is that feature extractors in normal perception are, by and large, mutually informationally encapsulated. Thus, for example, this view would predict that the shape extractor (as it might be) carries out its computations in a way that is insensitive to, and independent of, the information extracted by the color extractor (as it might be), and vice versa.

Though the dedicated feature view is a logically possible answer to our question, I believe that that logically possible answer is incorrect as a matter of empirical fact, in that it ignores the extensive evidence of significant integration between separate extractors. In particular, I want to motivate an alternative *integrative view*, on which feature extractors are integrated in (inter alia) the informational sense discussed above. That is to say, first, that the operation of

[8]The discussion in this subsection, and especially the presentation of evidence of informational integration in normal perception in §1.2.1, draws on material from Burnston and Cohen (2012).

[9]Clark (2000) argues persuasively that a picture of perception as a bundle of feature extractors is incomplete, and must be supplemented by mechanisms for binding extracted features to perceived objects. For present purposes I ignore this (serious) complication as well as all sorts of interesting and important questions about the relation between feature perception and object perception; for more on such themes, see Burnston and Cohen (2012).

one extractor can have causal effects on the operation of another. More than this, it is to say that there is a kind of counterfactual/informational integration between feacture extractors: the particular state taken on by a second extractor (hence, the information it carries about the world) depends counterfactually and informationally on the particular state taken on by a first (hence, the information it carries about the world).[10]

In §1.2.1, I will argue that, of these two competing pictures, the integrative conception offers us a more satisfying and empirically adequate way of thinking of perception. If I am right about this, then this will go some distance to showing that the forms of integration we found at the heart of synesthesia (§1.1) don't, after all, mark a significant qualitative distinction between synesthetic and normal perception.

1.2.1 Integration in normal perception

There are, it would appear, many processes in normal perception that point to the kind of informational integration under discussion. For reasons of space I give only a few (sadly, mostly visuocentric) examples that I take to be illustrative of the general theme.

A first kind of evidence of informational interactions within a perceptual modality comes from Field *et al.* (2009), who show that rod photoreceptors, which ordinarily function under scotopic conditions, provide input to blue/yellow opponent pathways in the macaque retina. What is interesting and surprising about this finding is precisely that, even though rod photoreceptors and blue/yellow pathways are generally thought to extract quite different ranges of distal features (indeed, in what one might have thought were almost entirely non-overlapping conditions), the information represented by the blue/yellow pathway turns out to be systematically, counterfactually dependent on rod photoreceptor informational output.

Here is a related, and similarly low-level, albeit somewhat speculative, case concerning color vision. Broackes (2009) has suggested that human deuteranopes employ dynamic input from their intact S-cone receptors to extract color information that is ordinarily subserved in trichromats by the (non-dynamic) output of L-cones or M-cones. Again, if correct, this proposal speaks to the existence of informational integration at the photoreceptor level: the suggestion is that red/green extractors are not encapsulated from

[10]There is a further, distinct, sense in which separate extractors may reasonably be said to be integrated in normal perception. Namely, there is reason to think that separate extractors can be directed at the extraction of a common feature, such that they run independently and in parallel, but such that their output is then combined and reconciled at some later point. Thus, for example, it is plausible that visual representations of depth are computed from the output of several such independent extractors, each independently running its own characteristic algorithm over its own characteristic range of input (as it might be, one or more computing stereopsis from retinal disparity data, a cluster deriving depth information from pictorial cues, a further cluster computing depth information from familiar object size information, and so on (for evidence of this kind of integration and further discussion, see Burnston and Cohen, 2012). I'll put this further sense of integration aside in what follows.

S-cone output, but instead that the state of the red/green system depends counterfactually/informationally on the state of the S-cones.

Moving above the photoreceptor level, there is increasing evidence that luminance/chromatic properties are used by the visual system to estimate shape, depth, texture, and more (see, for example, Mullen *et al.*, 2000; Kingdom, 2003; den Ouden *et al.*, 2005; Kingdom *et al.*, 2006; Kingdom and Kasrai, 2006; Gheorghiu and Kingdom, 2007; Hansen and Gegenfurtner, 2009). If that is true, then it means that extractors for shape, depth, texture, and so on, are not only causally triggered by, but informationally/counterfactually dependent on the information carried by luminance and chromatic feature extractors. And the McCollough effect (McCollough, 1965) and similar illusions suggest that some of those dependencies may run in the other direction as well: these effects suggest that extractors of chromatic color information are causally triggered by, and informationally/counterfactually dependent on, the particular informational states of form, orientation, and motion extractors. Likewise, there is abundant evidence of interaction between visual representations of luminance and motion. Thus, researchers have shown that motion processing is impaired or qualitatively different at isoluminance — e.g., that motion is represented as slower at isoluminance, that the direction of motion is far more difficult to discriminate at isoluminance, and that isoluminant stimuli can induce a motion aftereffect on luminance stimuli (Anstis, 2003, 2004; Howe *et al.*, 2006; Mullen and Baker, 1985; Thompson, 1982). Again, this means that extractors for visual motion are triggered by, and informationally/counterfactually depend on the information carried by luminance extractors.

Nor are the sorts of perceptual interactions of interest limited to intramodal cases. Thus, to mention some well-known examples, the McGurk effect (in which subjects' visual perception of a mouth's motion affects their auditory perception of simultaneously heard speech sound (McGurk and MacDonald, 1976)) and the ventriloquist illusion (in which subjects perceive a ventriloquist's voice as originating from the location of the visually perceived dummy rather than that of the auditorily perceived ventriloquist (Pick *et al.*, 1969; Vroomen and de Gelder, 2000, 2004)) give us reason for thinking that the state of at least some auditory feature extractors are causally, informationally, and counterfactually dependent on the state of at least some visual feature extractors. Similarly, the cutaneous rabbit illusion (Geldard and Sherrick, 1972) and cases of sensory substitution (e.g. Bach y Rita *et al.*, 1969) are standardly taken to show that there is two-way informational/counterfactual dependence between the states of tactile and visual feature extractors.

All of these findings give us reason for doubting that the perceptual mechanisms for the extraction of distinct features in normal perception are mutually encapsulated in the way that the dedicated feature extraction view proposes. In turn, they motivate taking seriously the alternative, integrative picture as the correct view about normal perception.

1.2.2 Morals

The instances of perceptual integration discussed above are, to all appearances, representative of the architecture of perception: informational integration (at many levels of organization) appears to be the rule rather than the exception in perceptual systems. Indeed, so overwhelming is the evidence in favor of integration that it can become hard to avoid seeing informational interaction in perceptual mechanisms once one begins to look.

On reflection, this is perhaps less surprising than one might have thought. First, given a fixed number of sensory receptors, and a large (if finite) number of perceptible features to which we are sensitive, it is more or less inevitable that feature extractors should share information at one level or another. Second, the very idea of perceptual computation, which is central to perception on nearly anyone's story, depends on sharing featural information. For, construed generally, perceptual computation means deriving values for new output features on the basis of features already extracted. Thus, when the perceptual system computes form from motion, or objecthood from edge locations, or illumination from higher order scene statistics (for example), it is using prior featural information — representations of feature exemplifications that have already been extracted — (possibly together with information about environmental regularities and channel conditions) to extract novel featural information.[11] As such, the novel, extracted features depend systematically on the features used as input to the perceptual computation, which is just to say that the former cannot be informationally encapsulated from the latter.

Given these points, it is no surprise to learn of the many instances of informational integration in perception. If anything, the question is why the dedicated feature extraction view should have seemed plausible in the first place (to the extent it ever did).[12]

1.3 Continuity and discontinuity

In so far as the dedicated feature extraction view and the integrative view offer us quite different pictures of the degree of informational integration present in

[11] There are, to be sure, forms of radical enactivism and other anti-representational views of perception on which this sort of computations, defined over representations, plays a far less central role. However, I do not believe that these views can offer a descriptively adequate account of perception (for particularly persuasive arguments to this effect, see Gallistel, 2008; Burge, 2010), so will put them aside in what follows.

[12] This is perhaps the place to mention that there is no in principle conflict between the view that normal perception depends extensively on the sort of informational integration we have been discussing and the view that there is substantial modularity/cognitive impenetrability (in the sense of Fodor (1983)) in normal perception. First, the idea of integration between feature extractors leaves it open that the extractors might exhibit Fodor's hallmarks of modularity — they might be, for all I have said, domain-specific, mandatory, fast, informationally encapsulated from central cognition, fixed in their neural architecture, and so on. Second, nothing that has been said above requires that integrative processes recruit should exhibit the "isotropic" or "Quinean" features Fodor (1983) takes to threaten modularity. For more extensive discussion, see Burnston and Cohen (2014).

normal perception, they make available different views of the relation between synesthetic and normal perception.

From the vantage point of the dedicated feature extraction view, the informational integration characteristic of synesthesia amounts to a pathological form of crosstalk between distinct, normatively encapsulated feature extractors. As such, accepting that view of normal perception is tantamount to endorsing a discontinuity view about the relation between synesthetic and normal perception. On the other hand, because the integrative picture conceives crosstalk between distinct feature extractors as a routine part of normal perception, the occurrence of such crosstalk in synesthetic cases won't, by itself, mark the latter as pathological in the same way.

This is not to say that the integrative view of (normal) perception is unable to see any distinctions at all between normal and synesthetic perception. For one thing, even by the lights of the integrative view, the particular forms and degree of crosstalk characteristic of, say, grapheme-color synesthesia are statistically abnormal. For another, there's nothing to prevent the proponent of the integrative view from recognizing that synesthetic representations are unlike non-synesthetic perceptual representations in being typically erroneous: presumably, for example, the induced synesthetic color representation occurring in a grapheme-color synesthete is (ordinarily) an erroneous representation of the color of the perceived grapheme.[13]

Such differences notwithstanding, the broad lesson stands: given the integrative view (but not given the dedicated feature extraction view), the integration present in synesthesia will look much more like an extension of integrative elements present in ordinary perception than an unprecedented, pathological case. To this extent, then, the integrative view of normal perception makes possible a continuity thesis about the relation between normal and synesthetic perception.

To see what such a continuity view amounts to, it may be helpful to compare the case of synesthesia against ordinary perceptual illusion, on the one hand, and tumor- or schizophrenia-induced hallucination, on the other. When I perceive the Müller-Lyer configuration, for example, I end up with a misrepresentation of the size of certain elements in the display. Plausibly, this occurs not because there is some radically discontinuous, pathological, and unusually error-prone mechanism for size representation at work in just these situations. Rather, the error comes about because the very same, highly reliable mechanisms for size and form perception that serve me well in ordinary contexts operate here as well, but misfire in predictable ways when extended to this configuration. Given all this, a continuity view about the relation between normal (veridical) perception and ordinary illusion seems appropriate. In contrast, perceptual (or apparently perceptual) hallucinations caused by certain tumors or schizophrenia are at least partly the result of mechanisms that *are* radically discontinuous, pathological, and unusually

[13]Here I ignore the complications connected with my own (somewhat idiosyncratic) account of errors of color representation (see Cohen, 2007, 2009). For the record, I don't believe that there is ultimately a clash between those views and what I say here.

error-prone. As such, a continuity view about the relation between normal perception and such tumor- or schizophrenia-induced hallucinations is much less plausible. The continuity view about synesthesia is the view that the relation between synesthesia and normal perception is, in these senses, closer to that between ordinary perceptual illusion and normal perception than it is to that between tumor-/schizophrenia-induced hallucination and normal perception.

As we have seen, the evidence reviewed above supports the integrative view over the dedicated feature extraction view of normal perception. And since the former but not the latter position supports a continuity view concerning synesthesia, the evidence for the integrative view also supports construing normal and synesthetic perception as species of a common kind.

2 Synesthetic and non-synesthetic associations: Compare and contrast

My second line of support for a continuity thesis about the relation between synesthetic and normal perception comes from consideration of similarities and differences between the two. After reviewing some of the evidence concerning such similarities (§2.1) and differences (§2.2), I'll turn briefly to the methodological question of just how we should think about the role of such similarities and differences in assessing the dispute between continuity and discontinuity views (§2.3).

2.1 Similarities

On the evidence, there appear to be interestingly deep similarities between cases of informational integration in synesthetic and non-synesthetic perception. Specifically, the evidence suggests that, when non-synesthetes are asked to make deliberate, nonce (non-synesthetic) associations between domains linked in synesthetic subjects, they do so in ways that — to a surprising extent — mirror the automatic, non-deliberate, much more stable, synesthetically mediated associations made by their synesthetic counterparts.

2.1.1 Grapheme-color intramodal mapping

We can begin by comparing grapheme-color associations made by synesthetes and normal controls.

What makes grapheme-color associations interesting as a test case for continuity between synesthetic and non-synesthetic perception is that, while grapheme-color synesthesia is by far the most common (Day, 2005) and (at least in the last twenty years) probably the most widely studied form of synesthesia, pairings between graphemes and colors do not play any significant role at all in the mental lives of non-synesthetes. Of course, non-synesthetes can deliberately construct (nonce) grapheme-color associations; but there is no prior reason to expect that the pairings they choose should be much like the pairings in grapheme-color synesthetes in any significant respect. As it turns out, however, grapheme-color synesthetes and normals display a surprising level of consistency (within- and between-groups) in pairing letters and colors (Simner *et al.*, 2005). Thus, both within and between groups, 'a' tends to be associated with red, 'b' with blue, 'c' with yellow, and so on (cf. Baron-Cohen *et al.*, 1993; Day, 2001, 2005; Rich *et al.*, 2005).

To be fair, Simner *et al.* (2005) go on to report differences between synesthete and control performance on this task. Specifically, they report that the particular grapheme-color pairings in synesthetes (but not normal controls) are mediated by frequency: higher frequency graphemes are paired with colors whose names are higher in lexical frequency.[14] They found that the pairings chosen by non-synesthetes were not mediated by these factors. Rather, they found that the pairings chosen by non-synesthetes were a function of the presentation order of materials and the typicality of colors (as measured by standard category norm ranking (Battig and Montague, 1969)).

Thus, it seems that synesthetes and non-synesthetes converge, to a surprising extent, in their choices of specific grapheme-color pairings, though differences in the properties of these pairings suggest that there may be different mechanisms underpinning the observed convergence. Given this situation, whether we should view grapheme-color pairings in synesthetes as two manifestations of a single psychological capacity will depend on how we individuate capacities. But even on the two capacities construal, the observed behavioral convergence suggests that synesthetic and non-synesthetic grapheme-color pairings are at least closely related.

Nonetheless, whether construed as two versions of one capacity or two separate capacities, there are clear senses in which synesthetes outperform non-synesthetes on grapheme-color pairings. Namely, synesthete pairings are more intrapersonally consistent over time, specific/fine-grained, and automatic, than those of non-synesthetes. (It is unsurprising that synesthetes outperform non-synesthetes on these measures, which are often used as diagnostics for the condition (Baron-Cohen *et al.*, 1987, 1993).)

2.1.2 Sound-color intermodal mapping

Much of what I've said about intramodal associations between graphemes and colors holds true as well for intermodal associations between sounds and colors. Once again, the comparison of interest is between the synesthetically

[14]Simner *et al.* (2005) note that a color term's lexical frequency correlates with its position in the Berlin and Kay hierarchy (Berlin and Kay, 1969; Lindsey and Brown, 2009), hence that synesthetes are also pairing high frequency graphemes with colors whose lexical expression is more fundamental in the Berlin and Kay typology.

mediated pairings between sound and color and the sound-color pairings made by normal controls.[15]

There are a number of interesting shared trends in the sound-color pairings made by both synesthetes and non-synesthetes. First, synesthetes and normal controls exhibit significant within- and between-group convergence in associating higher pitches with lighter/brighter colors, and lower pitches with darker colors. This convergence holds both in cases where the sounds in question are vowel sounds in natural language (Wundt, 1874; Ortmann, 1933; Karwoski and Odbert, 1938; Wicker, 1968; Marks, 1974) and in cases where the sounds are produced by (non-vocal) musical instruments (Karwoski *et al.*, 1942; Wicker, 1968; Marks, 1974, 1982, 1987; Hubbard, 1996; Melara, 1989; Ward *et al.*, 2006).[16] Second, Ward *et al.* (2006) report that synesthetes and normal controls exhibit significant within- and between-group convergence in associating certain instrument timbres with particular chroma (cf. Mudge, 1920): in their (somewhat hyperbolic) words, "musical notes from the piano and strings are, literally, more colourful than pure tones" (7). Third, Bleuler and Lehmann (1881); Voss (1929); Marks (1975) report a further shared trend: synesthetes and normal controls exhibit significant within- and between-group convergence in associating softer/louder sounds with smaller/larger colored patches. Though size is not a dimension of color, this shows yet another systematic similarity in the way synesthetes and non-synesthetes associate auditory and visual features.

These results are interesting not simply in that they reveal that synesthetes and non-synesthetes can both match individual sounds to individual colors; rather, they are interesting because they show that synesthetes and non-synesthetes agree in the way they systematically map particular auditory dimensions onto particular visual dimensions. Because of the specificity of the agreement in synesthetic and non-synesthetic pairings that these findings reveal, they suggest that there may be a shared mechanism mediating the auditory-visual associations in synesthetes and non-synesthetes.

Be that as it may, there are, once again, clear respects in which synesthetes exhibit superior performance in matching sounds to colors. For, unsurprisingly, synesthetic sound-color pairings have both higher internal consistency and higher specificity in color selection relative to the sound-color pairings made by normals (Ward *et al.*, 2006).

[15] Sound-color synesthesia — also called chromaesthesia — is another common and (at least until recent years in which grapheme-color synesthesia may have pulled ahead) much-studied form of synesthesia.

[16] More specifically, the association is between frequency (of the second formant, in the case of vowel sounds; of the fundamental, in the case of non-linguistic sounds) and lightness/brightness. See Marks (1975) for an extensive review of the 19th and 20th century documentation of this convergence.

2.2 Differences

Notwithstanding the similarities noted in §2.1, there are certainly also interesting differences between the cases (also as already noted). Indeed, in a provocative recent paper, Deroy and Spence (2013) appeal to such differences to argue that the continuity view is untenable. In particular, and though they consider several other differences as well that they take to be less telling against the continuity view, Deroy and Spence urge that crossmodal associations in normal perception are unlike synesthetic associations in being (i) bidirectional rather than unidirectional, (ii) transitive rather than intransitive, (iii) relative rather than absolute, (iv) malleable rather than rigid, and (v) plausibly expressed in non-human animals and human infants.[17]

Unfortunately, I want to argue that the evidence of difference these authors rely on in arguing against the continuity view is substantially less decisive than they suppose.

2.2.1 Unidirectionality and transitivity

Deroy and Spence (2013, 653–654) claim that (at least historically) researchers have taken synesthetic relations to be unidirectional/asymmetric (if a inducer I synesthetically elicits a concurrent C, then C will not in general serve as an inducer that synesthetically elicits I in the same subject), while they have taken crossmodal associations in normal perception to be bidirectional/symmetric (e.g., visual large size primes auditory low pitch iff auditory low pitch primes visual large size). Additionally, they conjecture that crossmodal associations in normal perception may be transitive, while there is no evidence indicating that the same is true of synesthetic associations (655).

However, though Deroy and Spence appear to treat these differences as central to their case against continuity, I think it is fair to say that the evidence they offer concerning unidirectionality and transitivity is, at best, mixed. On the side of unidirectionality, they themselves point out that a number of investigators have recently reported finding bidirectional synesthetic elicitations (Cohen Kadosh *et al.*, 2007; Cohen Kadosh and Henik, 2006; Cohen Kadosh

[17] Below I follow Deroy and Spence (2013) in restricting discussion to alleged disanalogies between synesthetic associations and crossmodal correspondences in normal perception, even though the latter constitute a proper subset of the informational integrations in normal perception discussed in §1.2.

Even within this range, I'll ignore for reasons of space several of the features they list but take not to be as clearly incompatible with the continuity view. (I agree with them that these other features are not serious obstacles to that view.)

Finally, I'll ignore Deroy's and Spence's more programmatic objections to the effect that running together perceptual integration in normal perception and synesthesia may exhibit a kind of bias, is likely to confuse investigators, or makes unconfirmed empirical predictions — all of which I find untroubling. After all, I would have thought it is problematic to exhibit such bias only if the view it favors is false (which is just what is at issue). Similarly, if the continuity view is true, then entertaining or adopting it will lead to desirable enlightenment, rather than undesirable confusion. Finally if it is true that the view makes unconfirmed empirical predictions, I suggest that that fact should be counted among its epistemic features rather than bugs (by both its fans and foes).

et al., 2008; Gebuis *et al.*, 2009; Johnson *et al.*, 2007; Knoch *et al.*, 2005; Richer *et al.*, 2011), but worry that the cases reported are so far limited in number and breadth. Of course, Deroy and Spence are surely right that it would be nicer to have a richer range of data on the question. However, I don't see why that should be counted as a reason to doubt the data points that we have so far, and that, on their face, seem to suggest that the criterion of unidirectionality does not pull synesthesia apart from crossmodal association in normal perception. Turning to transitivity, Deroy and Spence admit freely that the question of whether crossmodal associations in normal perception are transitive "has, to [their] knowledge, not been investigated in any detail yet," and that their case for it remains entirely speculative.

In short, the evidence Deroy and Spence present under this heading falls far short of a decisive demonstration of a significant difference between the two sorts of cases.

2.2.2 Relativity/Context-sensitivity

Deroy and Spence (2013, 655–656) hold that "the concurrent in the case of synesthesia . . . seems to be dependent solely on the nature of the inducer, and not on the other objects along which that inducer happens to be presented," whereas "the evidence concerning crossmodal correspondences suggests that they are very often relative. It is, for example, the relative, not the absolute, size that matters in the case of size-pitch correspondences."

Now, Deroy and Spence admit that this difference is less clearcut than it would seem, since, for example, it appears that the concurrent elicited by a bistable grapheme in grapheme-color synesthesia depends on the presence of surrounding characters that can induce one disambiguation rather than another (Dixon *et al.*, 2006; Rich and Mattingly, 2003). But they respond to this apparent counterevidence by redescribing the case in a way that does not involve contextually relative concurrent elicitation by a single, bistable grapheme inducer. On their alternative description, there is a single, bistable *shape*, which can then be resolved (with contextual cues) into one of two context-insensitive, unambiguous *graphemes*, each of which elicits a single concurrent. In other words, their suggestion is that the context-relativity occurs prior to the representation of graphemes, and that each grapheme synesthetically elicits a concurrent in a context-insensitive (/"absolute") way. In this way, they hope to hold on to their claim that synesthetic associations are context-insensitive ("absolute"), while crossmodal associations in normal perception are context-sensitive.

I find this attempt to explain away the putative counterexamples to their criterion unconvincing.

First, just as a matter of dialectical burden-pushing, it should be clear that the criterion at issue will fail in its intended purpose of distinguishing synesthetic from non-synesthetic correspondences unless Deroy's and Spence's interpretation of the evidence is mandatory, as opposed to merely available; and they have done nothing to show that it is.[18]

Second, note that the interpretation Deroy and Spence propose for the apparent effects of context on synesthetic grapheme-color associations can be applied just as well or poorly as a description of the apparent effects of context on crossmodal size-pitch correspondence (or any other apparently context-sensitive crossmodal association) in normal perception. Here, too, we might deny that there is one single size that can be contextually modified to elicit different crossmodally associated pitches. Rather, we could say that there are two different values of a parameter we might call 'proximal size', that is computationally prior to the representation of object size. And the thought would be that there is a single, ambiguous *proximal size*, which can then be resolved (with contextual cues) into one of many possible context-insensitive, unambiguous *(object) sizes*, each of which elicits a single crossmodally associated pitch. In other words, the suggestion is that the context-relativity occurs prior to the representation of object sizes, and that each object size crossmodally elicits an associated pitch in a context-insensitive (/"absolute") way.

In general, the lesson seems to be that it is no more or less possible to apply the contemplated strategy of redescription as a way of denying context-sensitivity in both the synesthetic and non-synesthetic cases. Pending further argument or evidence that would break this symmetry, it would appear that the proposed criterion of difference does not, after all, distinguish between the kinds of cases.

2.2.3 Malleability

Deroy and Spence further maintain that crossmodal and synesthetic correspondences are differentially malleable by training/experience. On the one hand, they point out that inducer-concurrent relations in adult synesthetes are stable over time and relatively invulnerable to modification by learning/experience. Whereas, on the other hand, they review evidence suggesting that "a subset of crossmodal correspondences (i.e., semantic ones) can be learned very rapidly, in a matter of trials" by adults (Deroy and Spence, 2013, 657).

But, once again, the alleged distinction in malleability is less clear than this lets on. First, Deroy and Spence are right to restrict their claim about malleability to a proper subset of crossmodal cases, since there are plenty of crossmodal correspondences (e.g., parade cases such as the ventriloquist illusion mentioned in §1.2.1, or the motion-bounce illusion (Sekuler *et al.*, 1997)) that appear to be (at least) significantly less malleable. This shows, minimally, that the criterion under discussion fails to divide cleanly between

[18] A further worry: the proposed re-explanation depends on supposing that a single context-relative shape is ambiguous between distinct context-mediated graphemic resolutions. If this is to avoid simply pushing back a contextually-mediated synesthetic link by one step, it had better turn out that we have good reasons for denying that what takes us from context-relative shape to a grapheme is a synesthetic correspondence.

synesthetic and crossmodal correspondences. But, second, if the unity of the class of crossmodal illusions withstands variation in malleability, as it appears to, then it's hard to see how variation in malleability could be a kind-distinguishing boundary that would separate off synesthetic from crossmodal correspondences in the way that Deroy and Spence say it does.[19]

2.2.4 Infraverbal expression

Deroy and Spence also propose to distinguish between crossmodal and synesthetic correspondences on the grounds that the former, but not the latter, are expressed in non-human animals (652) and human neonates and infants (645). Unfortunately, and as Deroy and Spence recognize in places (e.g., 645), it is controversial whether the specific cases they cite as evidence of crossmodal correspondence in infraverbals are crossmodal or synesthetic in nature, so this evidence fails to draw the distinction for which they enlist it. Moreover, it should be noted that one of the two leading current accounts locates the ontogenesis of adult human synesthesia in inadequate synaptic pruning over the normal course of development (Maurer and Maurer, 1988; Maurer and Mondlach, 2005; Baron-Cohen, 1996). Though this view, too, is controversial, if correct it would suggest that synesthesia is indeed expressed widely in early development.[20] Once again, it is hard to see this criterion as a representing a boundary between distinct qualitative kinds.

2.3 Methodological interlude

In this section I have compared cases of informational integration in synesthetic and normal perception, and have argued that the similarities are deeper, and the differences shallower, than it might seem. Without retracting any of what I have said, however, I want to emphasize that the comparative component of the case for continuity, as I understand it, does not rest in simply pointing to similarities between the cases, nor in (absurdly) denying the existence of disanalogies between the cases (as I suppose it would if it were an identity view rather than a continuity view). It is undeniable that there are both similarities and differences. But this observation leaves open whether such similarities and differences as there are merit treating the two

[19] A further concern about application of the malleability criterion is that apparent differences in malleability may reflect hidden asymmetries in regularity and reinforcement. Thus, it may be that synesthetic correspondences are, in principle, no less malleable than crossmodal correspondences, but seem so only because they are reinforced much more consistently in the experience of synesthetes relative to the transient crossmodal coincidences (such as those between, say colors and flavors) mentioned by Deroy and Spence (2013, 657).

[20] On the main alternative account, synesthesia arises from feedback disinhibition between primary sensory areas and higher cortical areas in the brain (Grossenbacher and Lovelace, 2001). It's worth noting that, though the feedback disinhibition story doesn't have to be told in a way that predicts the expression of synesthesia in early development, this account is also potentially conducive to the continuity view, assuming (not implausibly) that there is a similar form of feedback disinhibition at work in normal crossmodal integration.

kinds of associations as falling into different taxonomic kinds (as we do when, for example, we decide that, on reflection, it serves our explanatory purposes to treat jadeite and nephrite as different kinds) or not (as we do when, for example, we decide that, on reflection, it serves our explanatory purposes to treat adult and childhood expressions of chicken pox as different forms of the same underlying condition, or to treat whales and orangutans as members of the common kind *mammalia*). Which taxonomic choice we make in a given case depends not merely on spotting bare similarities or differences, but (among other things) on the explanatory needs in place, and how alternative choices serve those needs.

In applying these lessons to the choice between continuity and discontinuity views about the relation between synesthesia and normal perception, we should bear in mind the wide variety of cases of informational integration in normal perception, involving many different mechanisms at many different levels of perceptual processing, as discussed in §1.2. Consideration of this range naturally invites the worry that Deroy and Spence (2013) distinguish between synesthetic and non-synesthetic integration on the basis of differences that are not obviously wider or more important than those that separate instances of non-synesthetic integration. That is, if Deroy's and Spence's differences are sufficient to warrant a discontinuity view about synesthesia and normal perceptual integration, it is not at all obvious that we should count as instances of a common kind such normal perceptual phenomena as, e.g., postreceptoral integration, dominance, suppression, crossmodal dependence, spatiotemporal integration, and feature binding — which are all plausibly at least as different from one another across a range of criteria as synesthetic integration is from crossmodal association. My defense of the continuity view is grounded in the thought that it sometimes serves explanation to be able to see the commonalities at work here — while also acknowledging the differences. (Though I intend this lesson to apply generally, see §3 for one dramatic class of findings whose explanation seems to hang on being able to see such commonalities.) If this is right, it would seem that the continuity view represents an attractive explanatory framework for thinking about perception.

3 Synesthetic enhancement of crossmodal integration

The third line of support I want to offer for the continuity view comes from recent work by Brang *et al.* (2012) showing that synesthetic performance on integrative perceptual tasks is enhanced relative to normal controls.[21] This evidence adds to the case for continuity because it amounts to a surprising connection between synesthetic and non-synesthetic informational integration

[21] To be clear, I am using 'enhancement' merely to desribe an increased effect size; the claim is not that synesthetic perception is in these respects more accurate or reliable than, an improvement upon, or adaptively/teleologically superior to, perception in normal controls.

that cries out for explanation, and that is easily explained if the continuity view is correct, but not easily explained otherwise.

Brang *et al.* (2012) compare synesthetic and non-synthetic integration by exploiting two much-studied intermodal interactions between visual and auditory perception known to be present in normal/non-synesthetic subjects. The first is the so-called double-flash illusion, in which a single visual flash is perceived as two visual flashes when accompanied by two auditory beeps (Shams *et al.*, 2000). The second is the intersensory facilitation of reaction time — the finding that reaction times in congruent multimodal (simultaneously presented auditory and visual) stimulus detection tasks are significantly lower than reaction times for detection carried out in either modality alone (Hershenson, 1962), and, indeed, relative to what would be expected from a statistical summation of two independent, unimodal target detection processes (Miller, 1982, 1986).

These tasks are interesting for the purpose of assessing the continuity thesis, since they are known instances of perceptual integration in non-synesthetic subjects, and therefore afford an opportunity to test how and whether the relevant sorts of integration are affected by the presence of synesthesia. Significantly, however, Brang *et al.* (2012) chose to run these experiments on grapheme-color synesthetes. Since none of the stimuli in either of their tasks involved graphemes, the grapheme-color synesthesia of their synesthetic subjects should not have been engaged directly on these particular tasks.[22]

As usual, given our purposes of assessing the continuity/discontinuity controversy, we are interested in the comparison between synesthetes and normal controls, as measured by their susceptibility to the double flash illusion, on the one hand, and the intersensory facilitation of reaction time on a detection task, on the other. For, if the types of perceptual interaction one sees in normal perception are different in kind from what occurs in synesthesia, as per a discontinuity view, one would not expect that the presence of synesthesia would have any systematic effect on them. In contrast, if perceptual interaction in normal perception is continuous with — a weaker or less pervasive form of the same kind as — perceptual interaction in normal controls, one would expect that the presence of synesthesia would enhance such forms of perceptual interaction.

Brang *et al.* (2012) report results on both experiments that fall squarely into line with the predictions of the continuity view. Thus, in the double flash experiment, they found that (grapheme-color) synesthetes were significantly less likely than normals to report veridically that there was only a single flash accompanied by two beeps (viz., synesthetes were significantly more susceptible to the crossmodal illusion). And in the intersensory facilitation experiments, they found that synesthetic subjects benefited significantly more

[22]Brang *et al.* (2012) add that "None of the synesthetes experienced a synesthetic percept for any of the auditory or visual targets used. By utilizing stimuli that caused no synesthetic experiences, we can be confident that group differences reflect generalized processing, as opposed to differences driven by synesthetic percepts" (632).

(relative to their unimodal baselines) from a multimodal stimulus than did normal controls.

These results are particularly significant because they show not only that there are systematic similarities between synesthetic and non-synesthetic performance in associating elements within or across perceptual modalities (as do the cases discussed in §2.1), but that the effects are exaggerated in synesthetes even in domains where their synesthesia is unengaged. This fact is explicable on the hypothesis that the enhancement is due to an interaction between synesthesia and some shared associative mechanism operating in both populations. In contrast, if normal perception and synesthesia are fundamentally discontinuous, then one would not expect the whatever crosstalk underlies synesthesia to have any systematic effect on performance on tasks involving unrelated forms of perceptual integration (relative to the performance of normal controls).[23] It would appear, then, that the observed results are (at least partly) explicable on the continuity view, while it is very hard to imagine what a discontinuity-friendly explanation would look like. As such, these results strongly support the continuity view.

4 Conclusion

The initial question with which we began was how we should understand the relationship between synesthetic and non-synesthetic perception. The answer to this question that I've been advancing in the foregoing — the continuity view — is that the two are less different, hence that synesthesia is less of a pathological outlier, than traditional views would allow.

To be sure, there are ways of thinking about normal perception, such as the dedicated feature extraction view, that exaggerate the difference between it and synesthesia. But it has been my contention that these ways of thinking about normal perception are unjustified. I claim that once we adopt a more adequate view of normal perception — one that recognizes informational integration occurring within and between modalities — it is much more difficult to construe the (admittedly more extensive) informational integration characteristic of synesthetic perception as fundamentally different in kind. Moreover, the view that synesthetic and non-synesthetic perception are species of a common kind is far easier to reconcile with the observed systematic similarities between synesthetic and non-synesthetic cross-domain associations. And while there are undeniably also differences between synesthetic and non-synesthetic informational integration, there is reason (given standard explanatory needs in perceptual science) to regard these differences as relatively shallow, quantitative variations between elements of a common kind, rather than fundamental, qualitative, and kind-demarcating. Finally, the continuity

[23]Indeed, we might even predict that performance on such tasks would be *degraded* in synesthetes (relative to performance of normal controls), on the hypothesis that the (unrelated) perceptual integration occurring in the perceptual systems of synesthetic subjects may place additional load on capacities enlisted in the perceptual tasks we test.

view predicts the otherwise surprising finding that integrative effects in perception are enhanced in synesthetes relative to normal controls (even when the tasks do not involve the specific triggers that generate synesthetic percepts in the synesthetes). To the extent that having an explanation of these findings is better than not having one, these considerations further support the continuity view.

Of course, in advocating continuity I don't mean to suggest that synesthetic and normal perception are in all, or all interesting, respects alike. Nor do I claim that there are no differences between informational integration in normal and synesthetic perception. Rather, the claim is that that when we think about ordinary perception as displaying various kinds of integration that are less controversially present in synesthetic perception, this gives us an explanatorily richer way of thinking of the ordinary cases, and more fully reveals and explains what is shared by both types of perceivers.[24]

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