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The unity of haptic touch

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Haptic touch is an inherently active and exploratory form of perception, involving both coordinated movements and an array of distinct sensory receptors in the skin. For this reason, some have claimed that haptic touch is not a single sense, but rather a multisensory collection of distinct sensory systems. Though this claim is often made, it relies on what I regard as a confused conception of multisensory interaction. In its place, I develop a nuanced hierarchy of multisensory involvement. According to this hierarchy, touch turns out to be a single modality in that its various receptors assign their features to the same tangible objects. When we grasp an object a range of distinct properties—shape, warmth, heft, texture, etc.—are all felt to belong to the object, just as different visual properties are associated with a visual object. Paradigm multisensory experiences, on the other hand, involve associations between distinct perceptual experiences, as when the way something looks affects the way something sounds. Thus despite its functional and physiological diversity, haptic touch can be regarded as a single sense.

Keywords: Multisensory Experience; Perception; Touch

1. Introduction

Haptic touch is an inherently active and exploratory form of perception, involving both coordinated movements and an array of distinct sensory receptors in the skin. Through these many systems we experience an extraordinary range of properties, including vibration, temperature, pressure, shape, and weight. These many features are all processed by distinct (but interacting) physiological systems. Thus despite its apparent simplicity, the typical touch experience is a complex occurrence, involving many distinct physiological systems. The seemingly simple act of grasping a coffee mug is not, it turns out, so simple.

Any account of touch must address the possibility that touch is fundamentally different from the other senses in being a complex, or *multisensory*, form of experience. Call this possibility *the multisensory view* of touch, and contrast it with *the unisensory view*. The multisensory view seems reasonable given the inherent

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complexity of haptic touch (and several leading researchers have claimed that haptic touch is multisensory, e.g., Loomis & Lederman, 1986). While vision and audition seem unisensory, haptic touch seems to have an entirely different, multisensory structure.

Despite its plausibility, I believe the multisensory view of touch is mistaken. In what follows, I defend the unisensory view that haptic touch ought to be understood as a single sense. My argument is relatively simple: in haptic touch, the various cutaneous and kinaesthetic activations are coordinated (temporally, spatially, and otherwise) through exploratory action, resulting in a unified perceptual experience of tangible objects. The unified representations that result are structurally similar to those found in vision and the other senses, and can be contrasted with the kinds of representations typical of multisensory experiences. Haptic touch thus turns out to be a single modality, its various constituent systems aligned much like those involved in vision, audition, and the other senses.

The argument for this account is complicated, however, by the fact that, at present, no established criteria exist for deciding whether an experience is multisensory or not.[1] The intuitive conception of the senses—the view that the only major senses are sight, hearing, taste, smell, and touch, and that multisensory experiences arise from their various combinations—cannot be applied, since it both begs the question against touch and fails to distinguish problematic cases. In order to defend the unisensory account of haptic touch, I need to show that unisensory experiences can be distinguished from multisensory interactions by their structure.

I'll try to motivate the idea that unisensory experiences involve a relatively simple structure, in which qualitative features are assigned to individual objects. Though not essential to my view, I shall characterize this assignment in terms of "feature binding," and suggest that it is best understood as a kind of qualitative predication, where sensory systems are involved in the appropriate placement of sensory features.[2] To be clear, my claim is not that *all* unisensory experiences involve feature binding (there are many counter-examples). Rather, if a perceptual system (or group of systems) involves an assignment of sensory features to the same set of perceptual objects, that is sufficient for that perceptual system to be unisensory in nature.[3]

While I am sceptical that there is any single criterion of multisensory awareness, or that multisensory interactions form a natural kind, multisensory experiences do seem to build on unisensory structure, forming a general hierarchy of sensory interaction. At the lowest level of the hierarchy are what I'll call *apperceptive unities*, which involve experiences connected only in virtue of belonging to the same subject (and nothing more). At a slightly more involved level are cases of genuine sensory interaction, which involve an *associative relation* between distinct unisensory experiences (characterized by their unified predicational structure). An associative relation implies some connection between experiences, without specifying the nature of this connection. There are thus many ways of realizing such a relation. In virtue of such associations, experiences may suppress one another, or enhance one another, or one may dominate the other, etc., and there is no reason to think that any single mechanism is involved in every case of multisensory involvement. The idea of an associative relation is intended as a general concept that can explain a wide variety of multisensory interactions, while at the same time providing a means of differentiating unisensory from multisensory experiences.

The motivation for this view arises from a tension in the multisensory view itself. As Loomis and Lederman (1986) write:

> Although tactual examination of an object results in a phenomenologically unitary perceived object, the research literature acknowledges that what to the layperson is the "sense of touch" in fact comprises two distinct senses—the cutaneous sense and kinesthesis. (p. 31-2)

While the second clause claims that touch is comprised of multiple senses (i.e., is multisensory), the statement begins by acknowledging a certain phenomenological unity in haptic experience. This is suggestive. When we touch an object, we do not seem to have multiple overlapping experiences of the object (as we seem to when both looking at and touching the object). We seem to have only one experience of the object and its various features. One of my goals in this paper is to characterize this unity, and to suggest that on its basis haptic touch ought to be considered a single sense.

Some important terminological background before we begin: the term *tactual* is used to refer to any form of touch experience.[4] The more specific term *tactile* refers to perception mediated only by passive cutaneous stimulation, which includes sensitivity to temperature, pressure, vibration, and related features. The term *kinesthesis* refers to an awareness of our bodily movement and position; kinesthesis is part of a larger network that mediates many forms of self-awareness, from the orientation of our bodies to the amount of force applied to an external surface. *Haptic touch* involves cutaneous stimulations accompanied by kinesthesis (broadly construed to include external movements against our bodies and other forms of self-awareness). Haptic perceptions are what we usually mean by "the sense of touch." The challenge before us, to which we now turn, is to say whether or not haptic perception is multisensory.

Here is the overall plan: in the next section, I'll clarify the challenges involved in developing a criterion of multisensory experience, and offer some intuitively compelling examples to ground the discussion that follows. In section 3, I'll offer negative arguments against three plausible motivations for treating haptic touch as uniquely multisensory. In section 4, I develop the claim that unisensory perceptual experiences have a unique structure that differentiates them from typical multisensory experiences. In section 5, I argue that haptic touch possesses this unitary structure. Section 6 offers an initial account of the exploratory nature of haptic binding.

2. Clarifying the Challenge

Despite the recent surge in interest in multisensory experience, there are presently no adequate systematic accounts distinguishing multisensory from unisensory experiences.[5] It would be an entire project in itself to explain and catalogue the wide range of multisensory interactions, and offer necessary and sufficient conditions separating these many interactions from genuine unisensory experience. The philosophical project of individuating the senses is closely tied to such a project, and it has faced many difficulties (see, e.g., Grice, 1962/2002; Keeley, 2002; Noë, 2004; Nudds, 2004). My goals here are more modest: to offer some plausible and empirically-grounded reasons for thinking that haptic touch is not multisensory.

Let's start with some uncontroversial observations. We have several senses through which we experience the world, and these senses work together, coordinating at many levels. Many of our perceptual experiences are thus legitimately termed "multisensory." But the senses interact in a number of different ways, and there are many different kinds of sensory interaction. Consider having two unrelated perceptual experiences, such as looking at a red sphere while hearing a C# from the other side of the room. Intuitively, these appear to be two different sensory experiences. After all, the two experiences have a kind of independence; if one stops looking at the sphere, the auditory experience does not change, and vice versa. While both senses contribute to the subject's overall experience, it is merely a coincidence of two otherwise unrelated experiences. They possess *apperceptive unity*—they occur in the same subject at the same time—but little more.[6] It would be trivial to call such a mere conjunction a genuine multisensory experience. Or at any rate, such a mere conjunction—that is, a conjunction of experiences that have essentially no connection with one another—does not seem to be of much interest to those who study multisensory experience.

Paradigm multisensory experiences seem to involve a different, stronger form of interaction, which we can generally characterize as an *associative relation*. Suppose, for example, that the red sphere is the *source* of the note. Now we would experience the note originating from the same location as the sphere. If the sphere moved, the source of the note would move as well. If we moved closer to the sphere, the note would seem louder and more distinct. If the sphere is visually occluded—placed in a wooden box, perhaps—the sound would become muffled and distorted. In this example, we have two distinct signals, one visual and one auditory, providing reinforcing information about the same event: the sphere making a sound. This associative relation provides information about the event that could not be attained through any single sensory experience. The auditory experience seems to involve a sound that possesses a set of auditory qualities (perhaps structured something like this: sound[C#, location]). Nothing in the sound alone shows that *this* visual object is the source of the note. That requires an association between the visual and auditory experiences. Such associative relations occur frequently in perceptual experience, and they are a plausible necessary condition on genuine multisensory interaction, though there are a range of distinct mechanisms that relate sensory experiences. Sometimes, when two sensory experiences become associated, an alteration in the character and content of our sensory experience occurs. Such interactions by their nature involve more than apperceptive unity; they also often (not always) involve precise temporal and spatial coherence and associations between contents.[7] These influences occur in many paradigm multisensory illusions. Accidental co-occurrence with no interaction or association is one thing (and not very interesting); the truly interesting forms of multisensory awareness, at minimum, seem to involve an associative relation between different experiences. This notion of an associative relation is meant to be a general means of characterizing the structure of a range of distinct sensory mechanisms relating perceptual experiences.

We now face a difficulty: typical unisensory experiences *also* involve the coordination of information, often from different sources. We receive visual and auditory information from two eyes and two ears. Many different visual properties are associated with the sphere: a certain reddish color, a uniform spherical shape, a particular size, a smooth metallic texture, a motion. These features are all processed by largely distinct functional subsystems. The same visual object is both red and spherical and small and so on. Intuitively, there is an important difference between the multisensory case and the unisensory case, despite both involving the coordination of distinct sensory information. The question is this: in what way does the visual case differ from the C# and red case? What distinguishes the genuinely multisensory from the seemingly unisensory?

This is a very difficult question to answer, but it must be addressed. We need some way of showing that haptic touch—despite its functional and physiological complexity—can be considered unisensory. The proposal outlined here is that haptic touch, like vision and the other major senses, possesses a simple unity grounded in its representational structure. Unisensory experiences involve a single assignment of sensory features, whereas multisensory experiences involve higher-level relations between these assignments. Before motivating this claim, I will consider and reject several plausible ways of defending the multisensory view.

3. Three Criteria for the Multisensory View

I will now consider and reject three plausible ways of defending the multisensory view of touch (I'll reject two non-starters in passing). It does not follow that I take these characterizations to be of no interest for our understanding of perceptual experience generally. Sometimes we *are* interested in the functional or informational characteristics of a perceptual system, and it can be necessary to individuate things according to such criteria. My claim is only that such criteria fail to capture the relevant distinction between unisensory and multisensory experiences (especially when it comes to haptic touch).

3.1. The Functional Dissociation Criterion

Touch could be considered multisensory because—seemingly unlike vision and the other senses—it involves several functionally-distinct sensory systems.[8] Jerry Fodor (1983) characterizes sensory systems as a special kind of functional system (a system that performs a certain function). According to Fodor, input systems—including the major senses—are *modular*, meaning (among other things) that they are domain specific, fast-encoding, hard-wired, and informationally encapsulated. Input systems on this model are *functionally dissociable*, the primary operations (or functions) of the senses can be isolated from one another. Multisensory interactions can then be explained as interaction between these separate modules. This model of the mind has been highly influential in cognitive science and seems to be lurking in the background in many discussions of multisensory experience.

We can consider two systems to be functionally-distinct if the functioning of one system is (largely) independent of the other. The cutaneous and kinesthetic systems seem functionally distinct in this sense. One system subserves surface sensory awareness, the other awareness of the location and motion of our bodies; they also involve distinct receptor populations, afferent information channels, and neural processing centers, so they satisfy Fodor's modular criteria. A common means of establishing functional difference is the *double-dissociation criterion*: two systems *A* and *B* are functionally-distinct if, and only if, *A* can be maintained in the absence of *B*, and *B* can be maintained in the absence of *A*. The fact that we can largely doubly-dissociate cutaneous awareness from kinesthesis is evidence that the two are functionally-distinct systems.[9]

The involvement of functionally-distinct systems at first appears to be a good criterion of multisensory experience. Such a criterion can be simply stated:

> **Functional Dissociation Criterion (FDC):** An experience *E* is multisensory if it is produced by two or more functionally-distinct sensory systems. Two sensory systems are functionally-distinct if they can be doubly-dissociated from one another.

Despite appearances, such a criterion cannot be an adequate general account of multisensory experience. According to FDC nearly *every* perceptual experience is multisensory, from those with completely unrelated constituents to those that are seemingly unisensory. Every instance of apperceptive unity would trivially involve functionally-distinct systems, and unitary experiences themselves are composed of functionally-distinct subsystems. Visual motion and color are functionally dissociable: one can lose the ability to experience motion but retain color experience, and one can lose color experience but retain the experience of motion. Similar dissociations can be demonstrated in all of the perceptual modalities, across a wide range of features. Such a criterion would make being multisensory a trivial aspect of perceptual experience.

The FDC makes no distinction—as it seems we should—between mere apperceptive unities and experiences with some genuine coordination or association. For this reason FDC counts nearly any combination of sensory experiences as multisensory. This problem is compounded in the case of touch, since purely cutaneous, non-haptic touch experiences themselves consist of distinct receptor streams which are combined at higher levels of processing.[10] The complex nature of such processing means that tactile sensing itself is highly dissociable, involving a complex range of interacting subsystems. If haptic perceptions are multisensory on the basis of the FDC, then tactile experiences are similarly multisensory.

Analogous questions exist for kinesthesis, which is composed of cutaneous inputs, internal receptors, muscle feedback, and vestibular inputs. Similar reasoning could be applied to each of the other senses. In other words, according to FDC, all perceptual experiences are classed as multisensory, down to the simplest constituent systems.

One might suppose that we can find some functional difference between touch and the other senses. For instance, the constituent systems in touch are more independent than the systems involved in vision and audition. While we do not usually have visual color experiences without shape experiences, it seems we *can* have a purely thermal experience without roughness (as when we bring our hand near an open flame). The appearances here are deceiving, however. The functional connection between visual shape and color processing is strong, but so are the connections between most tactual processing streams. When an object impinges on a passive hand, the cutaneous signals are interpreted a certain way because the kinesthetic system indicates that the hand is not moving. When we feel heat from a flame, it is associated with a distal object (the flame) because there are no other signals indicating a solid object in contact with the body. Even in these passive cases, kinesthesis and other systems play a role. We rarely have purely passive touch experiences where movement or exploratory responses are not even possible. When we feel an object in contact with our bodies, we move around, aligning and focusing our receptors on the relevant properties of the object. In addition, cutaneous inputs provide vital information about the position and movement of our bodies. Haptic touch is not a mere conjunction of distinct sensory systems; its systems operate in a tightly coupled manner to generate novel and robust percepts of individual objects in the world. We'll return to this point later in the paper. We should note, however, that there is a difference at work here, only it isn't a difference in the strength of the functional connections. Rather, it's a difference in the nature of the connections; whereas visual streams converge more or less automatically when we look at the world, tactual features require active exploratory engagement. As we'll see, this is a difference in how the features are assigned to external objects, not a difference in the general structure.

We can easily diagnose where the FDC goes wrong: it's formulated without any serious regard for the structure of the resultant experiences. Our conception of multisensory experience ought to be sensitive to more than just the number of physiological or functional systems involved in the generation of an experience. Vision may be dissociable into separate functional streams (or stronger, as implied by Goodale & Milner, 1996), but it does not follow that visual experiences belong to multiple senses. The same is true of haptic touch. Like the other senses, touch involves a number of closely-connected sensory systems. Also like the other senses, these multiple systems share a strong form of unity grounded in the binding of sensory features.

3.2. The Shared Content Criterion

Another conception of multisensory experience might justify the multisensory view of touch. An experience could be multisensory if it involves content (or information) delivered via two distinct sensory channels.[11] Fred Dretske (1981), for instance, suggests that our perceptual systems (i.e., our senses) ought to be characterized as distinct channels of sensory information. As these channels feed into our overall experience of the world, the connections between them would seem to be ideal candidates for multisensory interactions. A similar view of sensory individuation (though more complicated in its details) is defended by Brian Keeley (2002). Keeley argues that the sensory modalities are evolutionarily appropriate routes into an organism that carry "information about the physical state of the world external to the central nervous system" (2002, p. 6). Sources, on these views, represent distinct aspects of the external world to which our nervous systems are sensitive. On both views, informational channels play an important role individuating the senses, and multisensory experiences can be explained as arising from interactions between these channels.

A recent paper by Casey O'Callaghan (2008) offers additional philosophical justification for this view (though O'Callaghan himself does not suggest or endorse such a view). O'Callaghan argues that cross-modal illusions—where one sensory experience has some illusory influence on another—require that there be some shared content between the different modalities. The basic reasoning is that if one sensory system is to influence the character of another, then information must be passed between the modalities.[12] One might suppose that multisensory experiences just are those that combine content from different sources. Consider the McGurk Effect (discussed by Driver & Spence, 2000). This illusion occurs when we perceive a phoneme that has been altered by being associated with a mismatched lip movement. For instance, if the sound/ba/is produced along with the lip movements that typically make the sound/ga/, it results in an auditory experience of the sound/da/. The visual information about the source of the sound alters the aural character of the sound. In order for this to occur, there must be some content shared between the two modalities. As O'Callaghan writes:

> It requires recognizing both a component of experiential content and an aspect of perceptual phenomenology that are shared by distinct perceptual modalities. Perceptual experience thus cannot be understood exclusively in modality-specific terms. (2008, p. 317)[13]

The claim that multisensory experiences involve information from distinct sources is also made in the empirical literature (for instance, multimodal neurons are those whose receptive fields are sensitive to more than one source of input; cf., Ghazanfar & Schroeder, 2006). It is a short step to the conclusion that such shared information characterizes multisensory experience. This criterion can also be simply stated:

> **Shared Content Criterion (SCC):** A perceptual experience E is multisensory if it has content c_1 (or information i_1) from source m via channel x, and content c_2 (or information i_2) from source n via channel y, where x and y are distinct channels.[14]

According to SCC, touch could be construed as multisensory inasmuch as the experience involves content or information from the surface of our skin as well as content derived from kinesthesis about the movement and location of our limbs. These two sources seem to involve distinct sensory channels, and these channels carry distinct information about the distal environment. For this reason, the overall haptic experience counts as multisensory.

The general claims leading up to SCC are fine as far as they go; the senses clearly interact with one another and genuine multisensory experiences surely involve contents or information from distinct sources. One serious problem is that the senses seem less separated than this criterion might require; rather than isolated channels of information, the senses seem to interact at many levels of processing. Thus, when embraced as a means of *defining* multisensory experience, it supports the conclusion that *all* (or nearly all) perceptual experience is multisensory. The SCC thus fails for many of the same reasons as the FDC (in fact, if channels are defined functionally then the two views essentially collapse into one another). Consider again the red sphere and C# case. The overall experience involves contents from distinct channels, and would thus count as multisensory. Not only the apperceptive unities are classed as multisensory, but once again supposedly unisensory experiences are as well. A typical visual experience seems to involve processing along many distinct channels, from the individual eyes and the different subsystems responsible for processing motion, shape, texture, color, and so on.

One obvious way to avoid the application of this criterion to seemingly unisensory experiences is to claim that the various subsystems in vision and the other senses count as a single channel, and that multisensory experience involves shared contents between *these* sensory channels (or functional subsystems above the level of a single modality). By itself, this is only an appeal to the intuitive view of the senses. But one cannot simply stipulate this; an independent argument is needed for such a claim.[15] Besides lacking sufficient warrant, such a stipulation begs the question in the case of touch. We want to know whether *touch* is multisensory, and it hardly settles the issue to just stipulate the answer.

One might similarly think I'm pushing too hard against the "radical view" that all of the sense are multisensory. It is worth reflecting on this point. Multisensory interactions are certainly more common than previously thought, and many of our perceptual experiences are multisensory. It would be a mistake, however, to completely throw away the concept of the individual sensory modalities. The individual senses have a special structure and importance that ought to be preserved by our best theory of perception.[16] I won't say much in defense of this claim here, except to note that if all of the senses are themselves multisensory, then (1) we would lose the ability to differentiate between perceptual experiences that appear quite different, and (2) it would completely undermine the multisensory view of touch (which again, is the view that touch is *uniquely* multisensory). The multisensory view hinges on the fact that touch is importantly different from the other senses in virtue of its unique physiological structure. This is partly right; the systems involved in touch do function in a manner unlike those involved in vision and audition. But it does not follow that touch is multisensory. The motivation for this claim likely stems from deep pragmatic considerations in the empirical study of touch, and is probably not intended as a robust theoretical construal of multisensory experience. While we have made great progress understanding the physiology of vision and the other senses, we still know relatively little about the cutaneous receptors, and much less about the complex interactions that occur in haptic perception. The multisensory view of touch may be primarily intended as a means of emphasizing this fact. Nothing in what I say here is meant to minimize or undercut the complexities involved in the study of touch, or to deny that touch involves a number of different functional systems operating in concert. My point is only that such facts do not constitute a robust general conception of multisensory experience, nor do they show that touch has a multisensory structure unlike that of the other senses.

3.3. The Multiple Stimulus Criterion

Let's consider one final attempt to defend the multisensory view of touch: the Multiple Stimulus Criterion (MSC). Multisensory experiences seem to involve coordination and associations between different kinds of stimuli. Vision, for instance, seems to involve a single kind of stimulus (light). Audition involves vibrations through a medium. Touch, on the other hand, involves more than one kind of stimulus. Kinesthetic inputs involve stimulations from dedicated receptors in our joints and stretch receptors in our muscles, temperature perception involves a distinct set of thermal receptors in our skin, and there are a range of unique receptor streams that code for features such as pressure and vibration. It may be that touch is multisensory because it involves the coordination of such disparate stimuli.

This view can easily reduce to one of the previous criteria. If we define stimuli by the receptors, we're essentially invoking a functional criterion. If we instead define the stimuli via their resultant contents (one for each stimulus), then the view becomes a variant of the SCC. It is also not simply the claim that touch, or any other mode of experience, is multisensory because it represents a range of distinct *properties*, as the other senses also represent a range of distinct properties. Properly understood, however, the MSC promises a novel means of characterizing sensory experiences. The idea is that there is a certain unity of the stimulus in vision and audition that isn't present in touch. While visual inputs all begin as a distribution of light on the retina, and audition begins with vibration through a medium contacting our auditory transducers, touch seems to involve a wider range of distinct stimulating inputs.

The main problem with the MSC is that we cannot even use the stimuli to say that two sensory modalities are different from one another, much less use it as a criterion for dividing unisensory and multisensory experiences. The problem is generated by so-called "sensory substitution systems," which replace the functioning of one sensory modality using inputs to another. For example, a tactile-visual substitution system (TVSS) uses a vibrating plate attached to a video camera to simulate visual inputs. Subjects who are trained in the use of such a system are only receiving tactual inputs, but the nature of the inputs (and their reactions) seem to be visual in nature. Subjects seem, for example, to be sensitive to looming and other vision-like effects (findings discussed by Noë, 2004). It is difficult to say whether or not the resulting capacity/experience ought to be considered tactual or visual (Noë, 2004 argues that we ought to treat such capacities as vision-like; see Prinz, 2006 for criticism). This suggests that stimuli are not what individuates the senses (or it would be obvious that TVSS was a kind of touch full-stop).

Still, one might think that substitution cases are irregular, and difficult to judge. Unlike vision and audition, touch certainly involves a range of distinct receptors, unevenly distributed through our bodies. And these receptors do seem to code for distinct properties. Temperature and weight and roughness are after all quite different. Two things can be said to resist MSC as a way of motivating the multisensory view. First, the various stimuli processed by touch are connected to each other in a way quite unlike the connections between tactual stimuli and those involved in the other senses. They seem to have a special kind of connection and unity grounded in their deep physiological connections. The stimuli involved in touch all arrive through the skin, where the various receptors code each signal. Almost immediately these various stimuli are combined and blended in various ways, leading to complex, novel signals at later stages of processing (Lumpkin & Caterina, 2007). For this reason, we can think of a tangible stimulus arising from our contact with external objects and their surfaces. This stimulus involves a range of distinct individual signals that combine to generate a unified experience of complex tangible properties. For example, if we touch a surface that is cool with very low friction then we will often experience that surface as wet. Similarly, our experience of material composition (whether something is wooden or metal) depends on the interactions between a range of distinct external stimuli. Such touch blends show that the different sensory stimuli strongly interact, leading to novel tactual experiences (cf., Katz, 1925/1989).

The second worry is that, like haptic touch, taste and smell also seem to involve distinct external stimuli, namely a range of distinct chemical properties which lead to distinct perceptual experiences. The sugar we taste as sweet has a chemical property quite unlike that found in the coin we taste as metallic. The different taste buds by their nature are sensitive to distinct external chemical properties. A similar situation occurs in smell. These distinct stimuli involved in sensory experience are not completely separate channels of information, but an interacting network of specialized transducers working together to produce a unified percept. It is thus once again difficult to isolate touch from the other senses in any strong manner (instead, we seem to have vision and audition on one side, and touch, smell, and taste on the other).

Many of these failures follow from the many challenges faced by those trying to individuate the senses. One of the strongest recent attempts to individuate the senses, that of Keeley (2002), involves aspects of all three criteria considered here (with some additional evolutionary considerations). According to Keeley, a sensory modality is a dedicated physical channel (FDC and SCC) that has adapted to pick up information in the distal environment (MSC). While I think this account is quite useful for its intended purpose (which I take to be offering an empirically-salient means of individuating sensory modalities in humans and other animals), it does not consider the implications of the deep interconnections between the senses so constructed, such that we can say of one perceptual experience that it is unisensory, and of another that it is multisensory.

To conclude with these inadequate attempts, it should be pointed out that a phenomenal characterization of multisensory experience cannot be invoked in defense of the multisensory view.[17] Most paradigm multisensory interactions have no identifying phenomenal character. We simply cannot tell from the phenomenal character alone whether or not an experience involves some strong association or alteration in character stemming from association with another experience.

4. The Structure of Unisensory Experience

My view is that haptic perception is unified in virtue of the fact that all of its physiological systems work together to assign sensory features to the same set of objects. The relationship between the functional subsystems in haptic touch is thus much like that found in the other sensory modalities, and contrasts with the structure found in paradigm multisensory experiences, which involved associations or coordinations between individual sensory features. My proposal is that unisensory experiences involve the direct assignment of features to perceptual objects, whereas multisensory experiences involve some higher-level relation between separate experiences.[18] While it is beyond the scope of this paper to fully defend the claim that a distinguishing feature of unisensory experience is its binding structure, the fact that such a view accords well with the empirical literature while offering a robust account of the difference between unisensory and multisensory experience lends a great deal of support to the idea. What follows is an attempt to show how such a view, if correct, offers a way of getting beyond the challenge posed by multisensory experience and of showing that haptic touch, despite its complexity, shares a special kind of unity with the other senses.

Most unisensory perceptual experiences involve multiple physiological systems and sources of content. Nevertheless, unisensory experiences have a strong form of unity called ''feature binding.'' Feature binding, as I understand it, involves the predication or assignment of distinct features to perceptual objects. The features are bound to *objects*, not each other. For this reason, feature binding is object-involving, and closely tied to our ability to perceive, segment, and group objects and events. Our knowledge of objects and their properties relies on this close association of features—we can distinguish a tennis ball from a baseball through sight because each has a certain set of distinct visual features. Further, the binding of features often generates experiential novelty; seeing a visual object does not seem to involve the mere co-occurrence of separate experiences (one for each distinct sensory feature).

The claim that feature binding is object-involving needs to be kept distinct from similar sounding claims about the *mechanisms* of such binding. While I believe that space-based accounts of perceptual binding—the idea that spatial locations serve as the bearers of perceptual properties—are not as plausible as object-based accounts (see, e.g., Matthen, 2005 for criticism of the space-based account), this is a debate about the mechanisms of sensory binding, not about the structure of bound experiences. Even if one thinks that spatial locations play a central role in sensory binding, it does not undermine the claim that when sensory features are bound what we experience are objects that possess a range of sensory features (e.g., we do not experience spaces as possessing certain features).

Further, I'm merely highlighting a distinguishing feature of unisensory perceptual experiences, not positing a necessary condition on them. There are many possible counter-examples to the necessity claim, for instance when one sees a ganzfeld—a uniform color field lacking any distinguishing features—it is highly likely that no sensory binding as I've described it occurs, yet we would consider such an experience unisensory (that we quickly go blind when exposed to such a field might support the view that sensory binding is a central aspect of visual experience, however).[19] I'm claiming that feature binding is at best a sufficient condition on unisensory experience. When an experience possesses a simple structure whereby sensory features are assigned to individual perceptual objects, without any further associative relations with other experiences, then we can consider that experience to be unisensory in nature.

While binding is most typically discussed in vision, some form of binding occurs in all of the senses. Auditory scene analysis, for instance, involves binding particular auditory qualities onto distinct auditory objects. When different sounds are heard, each of the many auditory features—distinct pitches, timbres, rhythms, locations, etc.—must be correctly associated with the correct sound (see e.g., Griffiths & Warren, 2004; Hall, Pastore, Acker, & Huang, 2000). When we hear a trumpet sound to our left, and a drum sound to our right, auditory binding occurs. We associate certain auditory features—again, pitch, timbre, loudness, rhythm, etc.—with each instrument's sound. Olfaction also involves binding features onto smells or odors, which seem best understood as distributed objects. When we smell several distinct odors, we must be able to correctly assign the various olfactory qualities to the appropriate objects. This is done by correctly assigning distinct chemical inputs to generate a single odor representation (Wilson & Stevenson, 2006). Such binding allows us to distinguish the sour odor of the lime juice from the earthy bite of chopped garlic in a single odor-experience. As in touch, the segmentation of odors onto distinct olfactory objects often involves a kind of exploratory action: we often sniff over a range of space in order to properly bind the many olfactory features to distinct objects.

For simplicity, I wish to characterize the claim that unisensory experiences involve the direct assignment of sensory features in terms of predication. According to this view, sensory features are "placed" or assigned to objects in the world. In vision, a set of unique features—including color, shape, texture, and motion—are all predicated, or bound, to visual objects. In audition, a range of auditory features are assigned to individual auditory objects, typically thought to be sounds. In olfaction, features or qualities are predicated of odors. We can characterize this structure in various ways, but the following simplified structure seems appropriate:

Unisensory: Visual-Object[texture + color + size + shape + motion, etc].[20]

Here we have an experience of an individual object that possesses a range of features. When we have a complex visual experience, we might perceive many visual objects with a unique distribution of visual features. These features do not take a single value, but form a distribution over the object (or set of objects). For instance, a visual object may be bluish in one region and greenish in another, or possess differently-shaped parts. We might see a blue object in front of a red one. Visual binding just is the process by which these distributions are properly assigned.The structure above is thus highly simplified, but captures what is essential about these kinds of experiences.[21] One form of evidence for such a predicative structure is the experience of change. When we see an object change color or shape, it is the very same object that so changes. We experience the same object as now possessing a different range of phenomenal properties. When an associative relation changes, we experience a change or alteration between distinct objects.

Multisensory experiences do not involve the direct predication of features onto individual perceptual objects. Instead, there is an association *between* bound experiences. These associations between sensory experiences are different in kind from unisensory experience, and facilitate tracking, attentional directedness, and reinforce our knowledge of objects and events in the world. This sort of coordination between the senses is revealed in a number of well-known multisensory illusions. Consider a representative example, the motion-bounce illusion (Sekuler, Sekuler, & Lau, 1997). When two visual targets on a screen start at the top corners and move to the opposite bottom corners, we experience the visual targets as crossing in the middle, tracing an X on the screen. If an auditory click occurs at the moment the two targets cross, then we are more likely to experience a collision, to see the two targets rebound away from each other in the middle, tracing a > < shape. The precise, coordinated operation of the two senses dramatically influences our perceptual experience, informing us that what could be seen as a crossing is more likely to be a bouncing. This motion-bounce illusion is just one of many examples of how the association of sensory information can influence and alter our perceptual experience.

The coordination involved in the auditory-visual case is often (though not always) sensitive to temporal and spatial continuity. A small divergence in timing or spatial location can often undermine the association and experiential effects. If the auditory click in the motion-bounce illusion were to occur much before or much after the visual targets cross, then we will not experience a bounce, and the auditory click would not alter our visual experience. What we experience is a higher-order association between sensory experiences. Genuine multisensory experiences involve some association between individual experiences. If an auditory experience is temporally and spatially aligned with a visual experience, for instance, it can result in an associative relation between the experiences:

Associative Relation: Sound[C#, loud] **&** Visual-Object[red, sphere]

Here the "&" represents an associative relation between the experiences. The red sphere is experienced as the source of the note, leading to a range of perceptual consequences. The relation is thus realized at many levels, and most likely through overlapping but distinct mechanisms of association. The two experiences share a relation that cannot be reduced to any of the individual constituents, but that exists between them (we could not tell that the sphere was the source of the note from sound or sight alone). Sometimes the associative relation leads to an alteration in the content and character of one of the constituent experiences:

Associative Relation$_2$: Sound [click$_{t1}$] $\rightarrow$ Visual-Object [bounce$_{t1}$]

This is a case of experiential dependence. The character of the visual experience depends on the precise alignment of the auditory signal. The particular associative relation realized here between the auditory and visual inputs has played a role in determining the precise content and character of the visual experience; it has influenced the interpretation of the visual input as a "bounce" rather than a "crossing." This appears to be the representational structure involved in the Motion Bounce case, and a similar structure occurs in many other paradigm multisensory experiences. Associative relations are subserved by many different mechanisms, from multisensory integration, super-additive responses, and sensory suppression. It is also likely that such relations are not discrete, but rather form a continuum. My account leaves open the possibility that some experiences are more strongly associated and mutually influencing than others.

One immediate concern about this account is its appeal to distinct perceptual objects to explain sensory binding. There appears to be a troubling circularity to the claim that sensory binding involves predication to a perceptual object, if that object is simply a bundle of bound features. To avoid this suspicion, let me be clear that I take perceptual objects to be ontologically robust, objective entities. It is true that such entities are experienced in a certain way, via certain represented features. Sounds, for instance, are most likely (though not necessarily) events of some kind, leading to the generation of air waves (Matthen, 2010; O'Callaghan, 2007). Sounds on this account are thus real entities in the world, though distinct from the objects that generate the sound. When we experience sounds, we do so by assigning a range of auditory features—pitch, timbre, loudness—to the auditory object (to that event). The same is true of visual and tangible objects, which are just material objects and their surfaces (albeit represented in a particular way, a crucial point). A tangible object is a real object, one to which we predicate a range of distinct tangible features. In other words, they are external objects that we experience through a range of perceptually salient features. Such objects are thus not merely the bundle of such representations, but the *bearers* of those features.[22] Objects thus construed are not what Aristotle called "proper sensibles." For instance, Aristotle took the proper sensible of vision to be color. On the view sketched here, however, colors are properties or features of visual objects, not themselves the objects of perception. Similarly, what Aristotle called the common sensibles—features shared between the senses, including number, movement, shape, and size—are properties possessed or assigned to perceptual objects, not themselves objects or bearers of properties (it makes little sense to think that *number* or *size* are the kind of things to which sensory qualities can be assigned).[23]

The alternative view is that perceptual experiences either lack structure entirely or they have some different structure. If we suppose perceptual experiences to lack structure, then we have no means (other than abstraction) of distinguishing between unisensory and multisensory experiences. Our experience of the world would be a "multisensory soup," with haptic touch merely one of the constituents. And in the preceding, I have taken pains to show that other means of dividing the cases fail to properly distinguish unisensory from multisensory, or to separate haptic touch from the other senses.

5. Haptic Touch

Let us turn now to the claim that haptic touch, with its many receptors and constituent systems, is much like vision and the other senses in (what I'm calling) its predicative structure. My view is that haptic touch, like the other senses, involves assigning a range of features onto individual perceptual objects. This structure is like that found in the unisensory case. Defending this requires two things. First, it needs to be established that such an assignment of features—binding—occurs in haptic touch. Second, the nature of this assignment needs to be more clearly distinguished from visual binding, since both senses seem to assign features to the same class of objects.

While sensory binding has been studied extensively in vision, and more recently in some of the other modalities, feature binding in haptic touch has not yet been studied in any detail. For this reason, there are few studies on the relationship between haptic features. Some evidence comes from the work on exploratory procedures done by Susan Lederman and her collaborators (see especially Lederman & Klatzky, 1987). These studies show that there is a close relationship between our exploratory movements and the set of features that are assigned to external objects. Some movements allow us to experience a range of features at once, while more complex movements generate more robust representations of objects and their features.

Consider a haptic interaction with a small metal sphere. This involves reaching out and picking it up, rolling it around in your hands, squeezing it, supporting it on your palm, pressing against it with your fingers, tracing its outline. Through these actions, a number of tangible features come to be predicated of the object—solidity, smoothness, coolness, hardness, spherical shape, weight, and size. If the sphere changes in some way, if it were to heat up, then we experience a change in the very same object, not a change in two different objects (while I am appealing to introspection here and in what follows, there is nothing mysterious about the examples cited. Of course, I would prefer evidence from careful empirical studies on haptic binding, but until such studies are conducted, examples like this will have to suffice). The structure of predication involved here is very similar to the visual case, and different from most multisensory experiences. Touch, like vision and the other major senses, does not involve any associative relation. It involves the direct predication or binding of sensory features onto individual objects:

Haptic: Haptic Object [texture + shape + roughness + hardness + thermal + etc.]

Even though the features involved in touch are largely processed by different sensory channels, they are assigned to the same tangible objects.[24]

Haptic touch thus does not seem, at least to introspection, to involve association between separate experiences (with their own perceptual objects). This follows from how we normally type experiences, in terms of their unity or content. For instance, when one has a visual and auditory experience, the two experiences can be characterized individually along many dimensions: qualitative differences, different contents, different objects, etc. One can easily abstract out the auditory part from the visual part. When one has a complex haptic experience, one does not seem able to distinguish the various parts in the same way. There does not seem to be a separate kinesthetic experience independent and distinguishable from one pressure experience, both of which are different again from the thermal experience, etc. Instead, one has a unified experience with different constituent elements, as occurs in vision. (Just as one does not have a motion experience separate from one's color experience, one does not have a thermal experience separate from one's texture experience.) In other words, a haptic experience does not involve a purely cutaneous experience that becomes associated with (or altered by) a kinesthetic experience.

One line of evidence for these claims comes from the kind of blending that occurs in typical haptic experiences. When an object feels cold to the touch, we are more likely to experience it as metal than wood. The thermal features become associated with the other tangible features, allowing for more accurate identification of, among other things, material composition, which plays a central role in our identification of objects through touch (Klatzky & Lederman, 2003). An important element of this view is that the binding found in haptic touch is continuous with, and not separate from, the binding found in passive cutaneous touch. That is, haptic perception involves the assignment of distinct features to the very same external objects felt through cutaneous touch. Haptic touch is thus not a separate form of experience, but rather an extension of cutaneous touch mediated by novel inputs provided by kinesthetic involvement. (For this reason, we could easily speak of the "unity of touch" in what follows.)

While it has already been argued that associative relations and sensory binding are distinct kinds of sensory interactions, this point was established largely by appeal to clear cases where the objects involved not only differed, but differed in kind (the C# and red sphere cases). There are strong philosophical reasons (dating at least to Berkeley) for supposing sounds to be distinct from the objects that produce them, but the objects of touch seem identical to the objects of vision. This poses a serious challenge to my account.

To see why, consider seeing and touching an object (sphere) at the same time. When we touch the sphere it seems we are binding several tangible features to it, but when we look at the sphere we seem to be assigning visual features to the very same object. The bearers of the properties seem to be the same. If this is right, then my account would seem to characterize visual-tactual experiences as unisensory, though they are paradigm instances of multisensory awareness. The following would be possible:

Haptic-Visual: Material Object [visual features + tangible features]

This would be possible because it seems as though Visual Object = Haptic Object, and since both sensory systems assign their features to the same objects, they will count as a single sense modality.[25]

This worry has its roots in one of the classic philosophical discussions of touch: Molyneux's Question. The question that vexed Molyneux in his letter to Locke concerned the relationship between visual shape and tangible shape, specifically whether an object like a sphere, known only through touch, could be recognized through vision (if a blind person were to have their sight suddenly restored, for instance). While not *exactly* the same issue, here the question concerns the relationship between visual and tangible features generally and their objects. Fortunately, there are good reasons for thinking that visual and tangible features are not bound to the same objects.

First, it simply doesn't follow from the identity of the objects that all of the qualitative features are bound together. The notion of an associative relation is meant to capture such cases of identity, and to offer an empirically-plausible and unified account of how such associations can explain a range of data, including experiential effects like dominance, facilitation, and suppression. While it is correct in one sense that vision and touch involve an awareness of the very same objects, a lot more evidence needs to be offered to suggest that vision and touch together assign their features directly to the very same objects. This is not itself an argument, but rather a way of removing some of the sting from the worry.

In addition, we have good reason for thinking that haptic features are not bound to visual features in a typical haptic-visual experience. While touch and vision share many qualitative features (size, shape, texture, etc.), these features are represented in distinct ways in vision and touch. That is, vision and touch might both represent shapes, but they do so in quite different ways. For example, geometrical features are processed more slowly in touch, and they play a diminished role in object recognition. While tangible shapes are determined largely by our manipulation and exploration of external objects, visual shape arises from distinct processes (shape from shading, for example). While this is essentially an invocation of distinct modes of presentation, it is not circular, for it is grounded in legitimate, objectively measurable differences between the two sensory systems. Along with the object of perception, the manner of representation is important and cannot be denied. Vision and touch represent objects and their features via distinct sets of properties that interact in unique, measurable ways.

6. Exploratory Binding

I have argued thus far that the predicative structure of touch is similar to that found in the other major senses. We can say a bit more, however, about the mechanisms underlying this predicative structure. In particular, we can explain how this structure arises by appeal to the unique role played by exploratory action in touch.

The role played by action makes sensory binding in touch unlike that in vision and audition. While visual features are bound whenever we look at the world, in touch we must reach out and investigate with our bodies in order to determine which features belong to which objects. It is through our exploratory movements that we are able to correctly segment and then identify the keys from among the many other objects in our bag, for instance. By grasping and pulling on one object, we can feel that it is coherent and individual, not part of some larger object. Once separated, we can actively explore each individual key, feeling for the right one. We can do this because a set of features—shapes, textures, sizes, materials, thermal profiles, compliance properties, and more—are correctly associated with the distinct objects. We have to actively explore an object in order to feel its various features (where "exploration" includes cases where an object actively moves relative to our bodies). Since exploratory action is necessary for our awareness of many tangible features, the predications in haptic touch are more dependent upon our current exploratory activities than they are in vision. If, for instance, we do not actively explore an object with our hands, then we cannot predicate the full range of tangible features to that object.

Our exploratory movements determine the range of tangible features that become connected. If I lightly touch an object with the tip of my little finger, I cannot feel its heft, or global shape, or overall size. I would feel other features, perhaps thermal properties and hardness. A different action, like grasping the object or enclosing it in my hands, would predicate additional features to the object. By stringing together a number of complex movements, a robust representation of the object can be generated. Despite this unique role played by exploration, the resulting structure of feature predication is the same as that in visual and auditory binding: a range of distinct sensory qualities are predicated to individual objects, with no overarching associative relations.

Susan Lederman and Roberta Klatzky (1987) have described haptic touch as possessing six to eight stereotypically performed exploratory movements, which they called exploratory procedures (EPs). These EPs perform two central roles. First, they allow for novel sensory activations. Lateral movements against the skin, for instance, create a unique shearing motion, activating otherwise silent receptor populations. Many similar activations occur only during properly coordinated movements. Second, EPs ensure the strong temporal and spatial coherence of the systems included in the tactual system. When we move our hands across a surface the motor feedback, feelings of agency, awareness of body position, and the cutaneous stimuli all become highly coordinated. The coordination of these many elements is achieved naturally by the coherence of our exploratory actions. When we grasp an object we immediately feel a range of distinct features predicated to it, and this feeling is a direct result of our grasping action. By pulling and pressing again several objects, we can properly segment and group them, predicating the appropriate features to the correct objects. Attention certainly plays an important role here, as it does in visual binding. Our exploratory actions allow us to attend to the many different features of tangible objects. When exploring an object with our hands for instance, we can shift our attention to its shape, size, or temperature, and feel that these features all belong to the object. Any fully-developed account of haptic binding will need to consider the role of attention in the assignment of sensory features (as well as in object segmentation and grouping).

It is not merely our outward actions that cause the close alignment of the tactual system. The many channels and subsystems involved in touch are also closely aligned and connected neurologically. Recent studies have revealed close associations between motor areas in the brain and the sensory areas involved in tactile discrimination. Catania and Henry (2006) give a good overview of the close associations that exist between different regions of somatosensory cortex, showing the close functional relations between the areas that code for different properties (see also Kaas, 2004). Large areas of feedback and interdependence actually support our capacity for active exploration through touch. These systems have become deeply connected, generating unified perceptual experiences from the coordinated inputs of many distinct processing streams. In other words, the motor system and the various cutaneous receptor systems have evolved in primates to produce a tightly coupled processing system, one perfectly tuned to the predication of distinct features onto perceptual objects.

One might still worry that exploratory actions merely associate distinct experiences, as occurs in typical multisensory cases. This worry is unfounded, however. To perceive an object through touch we must move our hands and actively explore its features. These movements generate novel inputs, from the stretching of the sensory surfaces, muscle-feedback, and active manipulation of the object (like shaking, scratching, and tapping). The experience involves a high degree of novelty; it feels quite unlike any individual cutaneous or kinesthetic experience. It is not as though our action merely alters or influences another of our experiences (as in paradigm multisensory experiences). Haptic perception involves a robust and novel form of experience, available to us only through coordinated exploratory actions (cf., Jones & Lederman, 2006; Lederman & Klatzyky, 2004, 2009). This is part of what it means to say that haptic experience has a unisensory character; while it involves a number of systems, they work together to generate a coherent, unified experience of the world.

7. Conclusion

To recap: there seems to be a hierarchy of perceptual unity. Seeing an object while hearing or smelling something completely unrelated involves only apperceptive unity;

the experiences just happen to occur in the same subject at the same time. Two experiences can become associated with each other, however, leading to a genuine multisensory experience. Seeing an object while hearing it sound a note involves such a relation, which cannot be reduced to any single perceptual experience. Sometimes, these associative relations result in alterations in the character and content of the constituent experiences. Such cases involve a kind of dependence or entanglement between the two experiences. Unisensory experiences do not involve any associative relations or experiential dependence: they have a relatively simple structure involving the predication of sensory features onto perceptual objects. A visual experience, for instance, involves a range of features appropriately bound to individual visual objects. Haptic touch also involves the predication of features onto individual tangible objects, but unlike vision, this process occurs in virtue of our exploratory activities.

Notes

[1] There are actually two closely-related questions here: (1) what makes an *experience* unisensory or multisensory? and (2) what makes a *sensory system (or set of systems)* unisensory or multisensory? These are distinct questions, involving different levels of explanation. Still, the questions are deeply intertwined, and cannot be independently answered; any account of unisensory experience must reference the systems that generate them, and vice versa. In what follows, I'll move as needed between experiential and system-level explanations.

[2] While this approach will be described in (mildly) conceptualist terms, it is compatible with non-conceptualism about perception. One could easily hold that some (or even most) perceptual contents are non-conceptual, so long as it is allowed that, at some level of perceptual experience, features are assigned to objects. If one denies that perceptual experiences have any such structure, then we have no means to of distinguishing unisensory from multisensory experiences (we end up with a "multisensory soup" view). There are many good sources for the conceptualist/non-conceptualist debate. The interested reader can start with the essays in Gunther (2003).

Similar accommodation can be made for adverbial and disjunctive accounts of perception. One could, for instance, give an adverbial account of seeing a table in terms of seeing it brownly, squarely, woodenly, and so on, where some binding-like connection exists between these various ways and the overall experience. For simplicity, I'll describe my view in conceptualist, representationalist terms (that is, in terms of sensory predication); supporters of other views could nevertheless agree—with a bit of translation—that unisensory and multisensory experiences differ in the ways outlined.

[3] The predications involved in touch do differ somewhat from those involved in vision and audition, however, for they arise largely from our exploratory interactions with tangible objects. (In this, touch is perhaps most similar to smell, which also involves a kind of exploratory binding grounded in active sniffing.)

[4] "Tactual" as I use it excludes pains, itches, tingles, and other bodily sensations. My focus here is on the perceptual aspects of touch experience, in particular, the active exploratory form of touch known as "haptic perception." Though I do not discuss pains and other bodily sensations in what follows, I believe that justification for setting them aside follows from my positive view: pains, unlike perceptual touch experiences, do not assign sensory features to external objects. I take up the distinction between perceptual touch and bodily sensation in more detail in another paper.

[5] For some recent empirical work on multisensory experience see Calvert and Thesen (2004), Driver and Spence (2000), Ghazanfar and Schroeder (2006), and Spence and Driver (2004). O'Callaghan (2008) is an informative recent philosophical work on the subject.

[6] This is similar to the "subjective unity" discussed by Bayne and Chalmers (2003).

[7] Cf., O'Callaghan (2008). Some multisensory interactions, notably those involving speech perception, occur even without precise spatial and temporal alignment. For example, see Jones and Jarick (2006).

[8] Loomis and Lederman (1986) seem to invoke a criterion like this when claiming that touch is multisensory.

[9] This is an idealization. We cannot doubly-dissociate the two systems because the cutaneous and kinesthetic systems are too deeply intertwined. A loss of cutaneous inputs would have a large negative effect on kinesthesis. Still, the systems are *largely* dissociable, for some imprecise conception of largeness, and this is certainly enough to motivate the multisensory view.

[10] See Lumpkin and Caterina (2007); there are even recently-discovered pleasure receptors in the skin, though the role of these receptors in haptic perception is unclear, see e.g., Löken, Wessberg, Morrison, McGlone, and Olausson (2009).

[11] Philosophers prefer to talk of *contents* that can be shared, whereas psychologists more often speak of *information* from distinct sources. I'm assuming that these two ways of speaking largely amount to the same thing.

[12] Or there is a common code shared by all the senses. This would seemingly lead to the view that there are no individual sensory modalities.

[13] While this admonition against understanding perceptual experience "in modality specific terms" comes close to the radical rejection of the individual senses mentioned earlier, the general point seems correct.

[14] While sources will typically differ as well, what individuates the senses on this view are that the contents arrive via distinct channels.

[15] I envision several ways this argument could be made (by appeal to attention, subpersonal versus personal processing, etc.). While I do not pursue it here, my positive view easily could be appropriated in defense of such a claim as well. The essential idea is that whatever relation unifies the visual channels would apply equally to the other senses, including haptic touch.

[16] See Nudds (2004) for a discussion of the significance of the senses.

[17] Keeley (2002) also argues that phenomenal character cannot help even in general sensory individuation.

[18] The claim that perceptual experiences are the kinds of things with robust structure is not uncontroversial. Others who hold a similar view (that perception is predicative or "feature placing") might be Burge (2009), Clark (2000), and Matthen (2005).

[19] See Avant (1965) for background on the Ganzfeld Effect.

[20] Of course, we could use different ways of notating the structure ("*o is F* & *o is G*" or "*o[F & G]*" etc.). I use the following only as a representative means of discussing the cases. More complex unisensory experiences would involve a distribution of objects: V-O_1[x,y,z, location], V-O_2 [x,y,z, location], etc.

[21] The details of how these feature distributions are actually bound to perceptual objects are not important here. This is, essentially, the binding problem, and is not the concern of this paper. I'm merely describing the salient characteristics of feature binding, not proposing an account of how it occurs.

[22] See Matthen (2005) and Pylyshyn (2006) for some background on this line of thought regarding perceptual objects.

[23] The more plausible possibility that locations serve as the bearers of sensory qualities is discussed above.

[24] This is not to deny that there are interactions between the systems involved in touch, for instance, motor activations involved in kinesthesis are known to suppress some cutaneous

receptors. This effect does not seem multisensory, but rather like the kind of effects that occur between the ocular motor system and other visual systems.

[25] Similar worries can be raised in taste-touch experiences, and can be addressed in similar ways.

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