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Many Molyneux Questions

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Abstract: Molyneux's Question (MQ) concerns whether a newly sighted man would recognize/distinguish a sphere and a cube by vision, assuming he could previously do this by touch. We argue that MQ splits into questions about (a) shared representations of space in different perceptual systems, and about (b) shared ways of constructing higher dimensional spatiotemporal features from information about lower dimensional ones, most of the technical difficulty centring on (b). So understood, MQ resists any monolithic answer: everything depends on the constraints faced by particular perceptual systems in extracting features of higher dimensionality from those of lower.

keywords: Molyneux's Question, shape, space, perceptual representation, intermodal transfer, crossmodal perception

I. Molyneux's Question About Cubes and Spheres

If you find something out by touch alone, can you confirm it by vision alone? This question was posed in completely general terms by a Spanish Muslim author, ibn Tufail, in a 12th century novel, *Haiy ibn Yaqzān*, translated and published in England in 1671, where it was widely read [Ockley 1960, Degenaar and Lokhorst 2017]. Tufail was a reductive materialist who believed that all qualities have a bodily essence; he concludes that a newly-sighted man would immediately recognize colour, though with new clarity and delight.

William Molyneux astutely narrowed the question down to shape—the first of many narrowing moves we will consider—and turned it over to John Locke in letters of July 7th, 1688 and March 2nd, 1693. Here is the 1693 version:

Suppose a blind man can tell by touch the difference between a sphere and a cube: Suppose then the cube and sphere placed on a table, and the blind man to be made to see. Quaere, whether by his sight, before he touched them, he could now distinguish, and tell, which is the globe, which the cube.

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Molyneux's Question (MQ) goes to the heart of many big questions about perception—innateness vs learning, the modal specificity of spatial representations, primary vs secondary qualities, and so on. Indeed, for many theorists, commitments on these and related issues lead directly to answers to MQ.¹ Thus, for example, because Locke's anti-nativism commits him to holding that ideas of shape must be acquired separately in each modality, he answers MQ negatively. Others answer positively on the grounds that shapes are spatial features and all modalities must share the structure of spatial representation.

In what follows we approach MQ from a different direction, by asking how perceptual systems construct representations of shapes and other higher-dimensional qualities from lower-dimensional input. For example, vision and touch construct spatiotemporally extended features from individual receptor-responses—point-data, we'll call them (though 'point' should not be taken in its zero-extension mathematical sense). In order to construct shape representations, perceptual systems have to integrate point-data over a region. Molyneux's question is inapplicable to point-data; colour (/intensity) is the only visual point-datum, and (*pace* ibn Tufail) it cannot be cross-identified with any tactual point-datum. However, the question is compelling when applied to the transfer of integrated constructs from one modality to another. We can ask:

Here is a spatiotemporal configuration C of tactile-point data. Suppose a newly-sighted man senses a spatiotemporal array C' of visual point-data. Can he recognize whether C' is constructed from point-data in the same manner as C ?

In this paper, we describe several phenomena that test particular instances of the transfer-of-integration question just posed—these are the “many Molyneux Questions” of our title. Many of these derive from known empirical studies, though not under the MQ rubric, and others are completely new, though empirically testable. The surprise is that a single answer to MQ cannot be supported: some of our questions are answered positively, others negatively. So, one general moral is this: although from a programmatic perspective it seems that there is only one issue behind MQ—Are shape-ideas learned by association?—this appearance dissipates under a closer examination of how higher-dimensional shapes

¹ Degenaar and Lokhorst [2017] survey philosophical approaches to the question.

relate to lower-dimensional ones, and how intermodal transfer of structural constructs works. Our main goal in the paper is to construct a geometrically based taxonomy of MQs, and thereby open up new avenues of investigation of perceptual construction and cross-modal matching.

II. Shape and Space

Locke construes MQ as a problem about shape. He believes that visual and tactual ideas of shape are formed separately, and, consequently, gives MQ a negative answer: the newly-sighted man hasn't yet learned the correspondence. (This interpretation does not do full justice to Locke's view; we qualify it in section III.) Locke does not, however, say how we learn shape-ideas. Presumably, we pick up some kind of similarity among their instances. What similarity is this, and how is it learned?

Many subsequent treatments of MQ attempt to answer such questions about the inner workings of intermodal comparisons. In his 'Letter on the Blind,' Denis Diderot [1749] observes that touch registers shape by tracing the outlines of an object with the finger or hand.² He concludes that tactual shape-ideas are constructed from temporal sequences of point-data and are hence not comparable to their visual counterparts. Whether or not one agrees, this is an important early attempt to say how shape-ideas relate to and are constructed from point-data. Unlike Locke, Diderot does not rest with saying that the idea of a cube is simply given.

Expanding on Diderot, Gareth Evans [1985] suggests that MQ begins with a problem about the perceptual representation of *space*, rather than of shape as such.³ Specifically, he thinks that the most pressing version of the Question (and the one that he takes Diderot, Condillac, Berkeley, and Leibniz to be disputing) is about "the relation between the perceptual representation of space attributable to the blind, and the perceptual representation of space available in visual perception" (370). But he disagrees with Diderot about the content of this relation. Observing that behavioural response to spatial cues is

² James et al [2007] provide strong reasons for thinking that such tactual exploration is a *perceptual* process.

³ For a discussion of the difference between shape and space in this context, see Schwenkler [2012a].

immediate and unmediated, Evans rejects the notion that the representation of external space could be modality-specific, and insists that that different modalities must share a single, inter- or a-modal, "behavioural" representation of space. He thinks that inter- or amodal conceptions of shape could be built on this shared conception.

Now, it is quite plausible that, as Evans argued, action-guidance from multiple modalities requires a shared representation of space.⁴ But by itself, this does not take us any distance toward a resolution of MQ. For it may be that the touch and vision system have to learn how to organize sensory data within the matrix that this representation provides.⁵ I feel something on my hand; I see something on my hand. How does the visual system know where the touch sensation I feel on my hand is, relative to the visual objects it registers? The behavioural space posit doesn't seem to answer the question.

Vision and touch have receptor sheets—the retina, the skin—with very different geometric/topological organization. They face very different problems formatting sensory data within the rigid parameters of a shared framework. One may sympathize with Evans's intuition that ordinary everyday behaviour demands a shared conception of space. But this does not guarantee that the newly-sighted man's visual faculty integrates information about higher-dimensional qualities in the same way as touch, or transfers such information smoothly to the common spatial representation with which both modalities will ultimately interact.

III. On the Perception of Wholes and Parts

What motivates the Evansian reconstrual of MQ as a question about the representation of space rather than (as it appears in its Lockean formulation) shape? One potential answer comes from an argument like the following:

Assume that the content provided by vision and touch consists in features at point-locations in a two-dimensional space. All that we *directly* see is an array

⁴ See Matthen [2014a] for a development of this idea and a critique of Evans's use of "behavioural space."

⁵ Evans assumes that if "the tactual concept is the same as the visual concept" then the answer to MQ is 'yes' (381). But this misses the fact that *deploying* a concept to classify patterns of sensory stimulation might need to be learned—how do we know that *this* configuration of visual ideas is instantiates the tactual concept?

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of point-colours; all we directly feel is pressure, heat, and pain at various point-locations on or in our bodies. Following David Lewis [1966],⁶ call this the ‘mosaic’ view. Now, spatiotemporally extended qualities such as shape and motion reduce to aggregates of these point-located qualities. The mosaic view implies that we see or feel such an aggregate simply in virtue of seeing or touching each minimal part of it—there is nothing else that vision or touch directly contributes.

Suppose then that a newly sighted person was able, by vision alone, to identify point-locations that she previously knew by touch. The mosaic view would hold that since the operations she previously employed to identify shapes were applied to point-locations not specific to touch, they are available for redeployment to visual locations. Conversely, if she was unable visually to locate those point-qualities, then these aggregative operations could not gain any purchase. Thus, Molyneux’s Question reduces to a problem of inter-comparability of point-located qualities, and thus to space.

This view holds that every idea of shape is undergirded by a more fundamental idea of space or of spatial position. The former is modality specific, one might think, just in case the latter is.

Now, the mosaic view of shape-perception is much more radical than the construction view implied by Diderot. The construction view implies that the subject, or her perceptual system, has to *do* something to form the idea—trace out a shape with her fingers and use working memory to arrive at a temporally extended sequence, or abstract a spatial pattern-similarity from certain traced-out patterns of points and unite them under a single idea. The mosaicist doesn’t allow that any such operation culminates in perception of

⁶ Lewis contrasts the color mosaic view with one in which visual perception is of ‘ostensible constituents of the external world.’ This is not the contrast we focus on. We do not assume that color mosaics are arrays of ‘sense data’ and we are not primarily concerned with how external objects are constructed from these. Our interest is in how point-data yield higher-dimensional data, and not in the separate question of whether the former are constituents of conscious states.

an extended idea. Rather, she insists that the whole is perceived merely in virtue of all of the parts being perceived.⁷

The mosaicist's reductive move is a mistake. True, there is a mathematical analysis of shape properties in terms of point-locations. For example, in Cartesian geometry, the surface of a sphere is definable as the set of points in space satisfying the equation

$$(x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2 = r^2$$

(where the centre of the sphere is $\langle x_0, y_0, z_0 \rangle$ and the radius is r).

However, the availability of a geometric analysis of shape in spatial terms tells us little about the nature of perceptual representations/ideas of shape, which may or may not be similarly constructed. According to mosaicism, perception of extended shapes is merely a combination of perceptions of the points that constitute the shape. In other words, ideas of extended shapes are Lockean complex ideas, built up by combining simples. Nothing more is required of your senses for you to be able to see/feel the complex idea *A and B* than for you to be able to see/feel *A* and to see/feel *B*. So also with shapes and the points that constitute them.

But this is problematic. To appreciate why, consider the following case:

Cookie Cutter Imagine a circular cookie cutter impressed motionless upon your back. This creates a set of contact points that jointly constitute a circle. You have a distinct tactual impression of each of these points individually (or at least of a multiplicity of short line segments constituted by them).

Cookie Cutter undermines the mosaic view. Mosaicists want to say that feeling a circle is nothing different from feeling a collection of points that together form a circle. Clearly, however, this is not sufficient to ensure that you can tactually "distinguish, and tell" that it is a circle. For nothing guarantees that tactual perception has a representational

⁷ To be clear, we have no definite opinion about whether Evans himself would have endorsed a constructivist or a mosaicist view. (His paper is a late draft that he could not revise before he died.) However, his critical remarks (following his reading of Pierre Villey, see below) about the blind man's integration of tactile information strongly suggest a constructivist view.

capacity for circularity.⁸ After all, every shape is reducible to a set of spatial positions. Yet even given a sufficient ability to distinguish the constituent spatial positions, there is no guarantee that one will have the ability in either vision or touch to discern every shape, or to differentiate each from all others.

In fact, it is empirically implausible to suppose that we are able to discern the circularity of a cookie cutter impressed on our backs. This is not merely a consequence of the poor resolution of touch with respect to points of contact on the back—touch is less spatially acute on the back than vision but it does not help to enlarge the cookie cutter so that sufficiently many segments of its circumference can be discerned. The perception of lines and shapes by touch is poor (relative to vision)—we can often detect collinearity, but this is easily disrupted and doesn't work as well across different body parts (for example, when one of the points is on the forearm and the other two on the palm).⁹ When you look at two red spots on the back of your left hand and two on the back of your right hand, it's easy to adjust your hands so that they line up straight. The same is not true for vibrotactors sensed by touch alone.

IV. Generalizing MQ: Dimensional Integration

Cookie Cutter gives us reason to doubt that the perceptual representation of circularity, or by extension sphericity, is composed of ideas of position. The point is reinforced by reflection on visual form agnosias, in which “patients with normal acuity cannot recognize something as simple as a square or circle” [Farah 1990: 1]. For example, Goodale et al [1991] reported that after brain damage due to carbon monoxide induced hypoxia, their patient DF was unable visually to identify whole objects such as her mother's forearm though she retained the visual ability to discern the fine visual details, such as hairs on the forearm. DF's brain had, in short, lost the ability to integrate visual parts into a whole.

⁸Cohen [in press] emphasizes problems of such intermodal differences in representational scope, and their implications for the operation of sensory substitution devices. These questions must be taken case by case, and empirically.

⁹ The question has been investigated by Patrick Haggard and his co-workers. See, for example, Haggard and Giovagnoli [2011]. It is worth noting that Haggard distinguishes the questions of tactile localization and those of tactile pattern recognition. The former set of questions has been investigated ever since the dawn of psychophysics, the latter only very recently.

(Similar form agnosias have been reported for touch: see Reed and Caselli [1994].) Conversely, some patients with Balint's syndrome successfully report visually perceived whole shapes and yet are unable to report on or reach toward the points in space where these whole shapes are located, which some have taken to indicate that they have a limited visual representation of spatial location.¹⁰ These findings show that perception of spatial points and perception of shape come apart in at least one direction, and possibly both.

These cases invite us to consider a within-modality version of MQ:

Suppose that a mature woman who has been sighted since birth is plainly shown a circle (or a sphere). Suppose further that she is able to see every part (or facing part) of it. Would she be able to identify the whole object as a circle/sphere by sight alone?

The case of DF shows that the answer to this question varies from person to person. Independently of any tactual knowledge that she might employ, this mature woman was consistently unable to perform the identification task. This puts *Cookie Cutter* into perspective. In *Cookie Cutter*, unimpaired perceivers lack the ability to integrate shape information in one modality, though they possess it in another. We might call this a *normal form agnosia* of the deprived modality (i.e. of touch). You may have sensory awareness of points satisfying the geometric analysis of circularity and yet not have a perceptually given idea of circularity.

We can now generalize the problem emerging from our consideration of form-agnosia. Space is three-dimensional and time adds an additional dimension. Shapes are n -dimensional spatiotemporal features, for n greater than zero. Perceptual systems construct these higher dimensional features from information about lower-dimensional ones—lines are detected by integrating information about points; surfaces from information about points and lines, and so on. Call this *dimensional integration*. The question we posed in section I can now be restated: given a feature F that is integrated from lower-dimensional information in one modality, and given equivalent lower-dimensional information in another modality, does the perception of F follow automatically in the second modality?

¹⁰ This interpretation is controversial; cf., Robertson et. al [1997], Kim and Robertson [2001], and Robertson [2004].

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Combining the spatial coordination problem from section II (how are point-data in different modalities regimented in a single representation of space?) with the problem of dimensional integration just broached suggests a generalized construal of MQ, which we formulate inductively. First, space-MQ:

Basis Points are zero-dimensional. The representation of space is constructed from point-data and their inter-relations, such as distance and direction.

Representing these relations is non-trivial; it is not implicit in the output of individual receptors. Does the spatial basis of constructed shape-ideas transfer from one modality to another?

Now, shape-MQ:

Dimensional Integration Suppose that you possess equivalent n-dimensional information in vision and in touch. Suppose, further, that you can, by the use of one modality, reliably identify an n+1-dimensional spatiotemporal feature *F*. Can you, in virtue of this same integrative ability, reliably identify *F* by means of the other modality alone? (Assume, for the sake of vividness, that you have newly acquired the second modality. Are you able to identify *F* by means of the newly acquired modality?)

The above formulation of MQ breaks the formation of shape-ideas into steps and allows for a number of variations, which we will discuss in what follows. The resulting taxonomy systematically organizes a set of otherwise disparate questions about intermodal transfer that have held philosophical and scientific interest on their own. It suggests a new range of questions of the same type, sheds light on similarities and differences between members of the family, and allows us to formulate a much-augmented set of principles and questions concerning the intermodal transfer of spatiotemporal organization. We anticipate that these questions will be significant in the context of the on-going discussion of cross-modal perception.

V. The two- and one-dimensional questions

In his recounting of MQ, Locke says that vision acquaints us only with a "plane variously coloured." That is, he thinks that (contrary to what we assumed in our simplified discussion

of Locke in section II) there is no simple idea of a sphere. Rather, he believes, vision gives us something like Figure 1.

Figure 1 about here

Figure 1: Do we have visual awareness as of a sphere in the scene depicted above, or only of a circular 'plane variously coloured'?

According to him, we are directly aware of a two-dimensional projection, a pattern of coloured patches within a circular outline, without depth information about any of the patches. There is some feature of this pattern that we learn by experience to associate with the tactile idea of depth, thereby allowing us to infer that what we see has depth. Thus, the visual idea of a sphere is, in Locke's view, complex and multimodal. It has, as its components, a visual idea of coloured patches constituting a circle, each added by association to a tactile idea of depth.

Acknowledging this complication in Locke's thinking, John Mackie [1976: ch 2] argues that Locke's negative answer to Molyneux might be based on what he takes to be the role of association in the extraction of depth information, not on the modal specificity of visual ideas.¹¹ The newly sighted man looks at the globe and the cube. He is directly aware only of two-dimensional planes variously coloured. He has no visually activated complex idea of two distinct three-dimensional shapes because he lacks the association between the visual ideas and the tactile idea of depth in the two cases.

Mackie suggests a two-dimensional version of MQ, which we formulate as follows:

Suppose then the cube and sphere placed on a table, and the blind man to be made to see. Quaere, whether by his sight, before he touched them, he could now distinguish, and tell, which appears as a circle variously coloured, which as a rectilinear figure.

¹¹ Is the newly-sighted man aware right away of coherent two-dimensional displays of colour similar to those available to those sighted since birth? This is what Locke thought, but the assumption is dubious, and infects some treatments of the problem up until the present (see. Schwenker [2012b]).

Mackie says that though Locke had answered the original, three-dimensional Question negatively, he might have given a positive answer to the two-dimensional Question. For Locke held that simple ideas of primary qualities resemble the qualities themselves. Since shape is a primary quality, it follows that both the visual and the tactual idea of a circle resemble a circle. Depending on how this similarity works in the two modalities, and on whether we possess the ability to recognize similarity/difference between ideas that resemble the same primary quality, it is possible that it would be sufficient to secure immediate recognition (29).¹²

It is worth observing, first of all, that Mackie relies on mosaic theory. The mosaicist ascribes the failure to perceive higher-dimensional wholes—lines and shapes—to the failure to perceive some punctate part. Why, on Mackie’s reading, would the newly sighted man recognize flat circles? Because he is able to see their constituent points laid out in two-dimensional space. Why does he fail to discern a three-dimensional solid? Because vision provides him only indirect indications of distance that he has yet to learn. Crucially, the capacity this man lacks is supposedly not visual; rather, it is the learned capacity to associate distance with various visual cues that are implicit in the “colour mosaic.” This way of putting the problem overlooks an additional difficulty—suppose that vision did give us the distance of each part. Would it follow that the newly sighted man could then recognize a sphere? No, because vision might not be able to integrate the totality of location-distance pairs into a form where it matches the pre-existing idea of a sphere—and the same goes for recognizing a circle.

In any case, Mackie is right to notice the consistency of different answers to versions of MQ in different dimensionalities, in this case a difference between the 3D and the 2D MQs (cf. van Cleve [2007], Connolly [2013]). But his line of thought about the two-

12 For a candidate Lockean understanding of this immediate recognition, see Bennett [1965]. In the opposite direction, note that the sense of touch is unlike vision in that its input is not a flat Euclidean two-dimensional array, but rather an array of contact points on the skin together with (possibly incomplete) proprioceptive information about the three-dimensional disposition of these contact points. This brings to the fore the Reidian warning (see below) about possible differences between the kinds of information that are available to the two modalities. How does translation from one to the other work, and how does this affect inter-modal transfer? The answers to these questions, which bridge the two- and three-dimensional MQs, are not a priori or obvious.

dimensional MQ is not in fact supported by experiments reported by Ostrovsky et al [2009] and Held et al. [2011]. Project Prakash was a surgical clinic that removed cataracts from Indian children and adolescents and replaced them with intraocular lens implants. When sight was thus surgically restored to congenitally blind patients, it was found that they could not immediately visually identify two-dimensional shapes (displayed on a computer screen) that they could identify by touch. The newly sighted subjects did not exhibit an immediate transfer of their tactile shape knowledge to the visual domain, these experimenters write. This supports a negative answer to two-dimensional MQ (and presumably to the three-dimensional version).^{13,14}

Mackie's two-dimensional version of MQ is illuminating. We note that it is easy to construct a one-dimensional version.

Suppose that the newly sighted man was shown a rope stretched tight and one that droops in a catenary curve. Could he distinguish and tell by sight alone which was which?

Diderot uses an example of this sort to argue that the blind lack a "simultaneous" representation of space, as Evans calls it. A blind person has to run her finger over such ropes, and Diderot argues that her concept of shape therefore integrates spatial information gathered over an extended interval of time. But, he continues, sighted persons are capable of seeing the straight and the curved in a single instant. Thus, blind people have a different kind of representation of the straight and the curved.

In saying this, Diderot here heeds a methodological warning arising from Reid's observation that there can be significant structural differences between the representational resources distinct modalities bring to the task of representing a feature

¹³ Similar negative results were reported much earlier, e.g., in the celebrated "Cheselden case" of a congenitally blind Molyneux subject restored to vision by the removal of cataracts (Cheselden [1728]). For more on the history of Molyneux cases, see von Senden [1932].

¹⁴ Of course, these results do not, all by themselves, confirm Locke's treatment of the matter. As we have noted, there is also the possibility that the newly sighted find it difficult to form a coherent two-dimensional visual expanse, and that there are difficulties in transitioning between the way three-dimensionality is presented in the two modalities.

F.¹⁵ Reid’s argument is contentious, but whether or not we endorse his substantive views about touch and vision, we should surely accept his underlying methodological assumption —namely that the structure of the world leaves different options open to individual perceptual modalities (which, therefore, needn’t coincide in the options they select) for how their representation of the world is put together. There’s no direct match required between the structure of the worldly feature, *F*, and the structure of a modality’s representation of *F*, or, a fortiori, between the structures selected by different modalities for the representation of *F*. Mirroring Reid’s claim about structural differences between tactile and visual representations of shape, Diderot identifies a putative difference between the concept of shape in sighted and blind perceivers — the latter, he thinks includes a temporal element while that of the sighted person does not,¹⁶ and infers on this basis a negative answer to our 2D MQ about shape. (Note the extrapolation from shapes to space here. Note also the mosaicist assumption: failure to discern shape traces to the failure to locate segments in an inclusive space.)

While Diderot’s reasoning is eye-opening, there is evidence that complicates his negative answer. Evans (369) quotes a memoir of a blind author, Pierre Villey, who reports that his memory of three-dimensional objects “appears immediately, and as a whole.” This report, if credible, shows that the ideas he forms do not have the temporal structure Diderot assumes they would. They also raise the possibility of a shared representation of space that forms a template for temporally sequential haptic exploration. It is worth noting in this context that we engage in temporally extended visual exploration of three-dimensional objects¹⁷—for example, we walk around large objects, taking in their three-

15 Namely, he holds that touch and vision use different geometries: according to him, touch does, while vision does not, represent space and shape as Euclidean (*An Inquiry Into the Human Mind on the Principles of Common Sense*, ch 6-7).

16 However, Diderot is wrong to treat a difference in the spatiotemporal range of vision and touch as marking, by itself, a genuine structural difference between the two. After all, there are ways of controlling for the former sort of difference — e.g., in this case, either by restricting visual range (by the use of blinders) or increasing tactile range (presenting the entire straight or curved shape all at once on the subject’s back).

17 See Matthen [2014 a, b] for discussion of how sensory exploration affects the ontology and epistemology of perception.

dimensional shape. Matches between visual and haptic exploration remain empirically obscure.

VI. Learning and MQ: Graded transfer

Project Prakash experimenters also studied how visual parsing is learned—i.e., how newly sighted people learn to segregate the visual scene into distinct objects (Ostrovsky et al 2006). They note, in an echo of Locke's "plane variously coloured" remark, that "Real-world images typically comprise many regions of different colors and luminances" (*ibid.*, 1484). They tried to find out how newly sighted patients learn to resolve such scenes variously coloured into discrete objects. Figure 2 shows some of their results. They write that in these patients, "prominent figural cues of grouping, such as good continuation and junction structure, were largely ineffective for image parsing."

By contrast with these "Gestalt cues" (as they might be called), motion cues were almost immediately significant. When one shape, such as a sphere, moves in front of and across another shape, such as a cube, it creates a constantly changing joint boundary. Sighted people immediately see the three- dimensional scene for what it is. As it turns out, newly sighted people learn this very quickly. In other words, they are quick to learn motion cues of three-dimensional arrangement, but much slower to learn Gestalt cues. (But, of course, they had a pre-existing tactual idea of three- dimensional layout.)

Figure 2 about here

Figure 2: Support for Mackie's interpretation of Locke. Newly sighted patients have difficulty recognizing occlusion in displays B to E. Some had difficulty identifying the longest curve in F, and none were able to resolve display G into faces of a cube. (c) indicates how a simple display resolves into three distinct shapes. The patients were unable to parse the displays on the top row of (e); the bottom row shows how a simple luminance-contrast algorithm performed. (From Ostrovsky et al [2009;] used by permission.)

Different visual cues (Gestalt cues, motion-based cues) are associated with different shape- and space-related properties, but these associations are learned at different rates.

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This shows that, contrary to Locke, learning by association (or simple classical conditioning) is not by itself sufficient to explain how newly sighted persons learn visually to recognize three-dimensional shapes and spatial distributions. If it were, then the associations between Gestalt cues and depth should be no more difficult to learn than those between motion cues and depth. The associations exploited here are domain-specific. So the learning must involve something more than mere association. Specifically, associations between visual representations of motion and tactual ideas of depth are not all of a single kind. As Held et al [2011: note 10] write: "The rapidity of acquisition suggests that the neuronal substrates responsible for cross-modal interaction might already be in place before they become behaviorally manifest."

Here, then, is another version of Molyneux's Question:

Suppose that a cube and a sphere are placed on a table, one in front of and partially obscuring the other. How long after restoration of sight would a previously blind man be able to distinguish the two objects? Would he be quicker to distinguish the two objects if one of them were moved?

On the classical idea that all learning is associative and all associative pairings between two simple features are made at the same rate, the answer to the second question should be no. But this is not experimentally supported. Just as there are differences among modalities with regard to how they process the different forms of information their receptors provide, so also there is a difference in learning mechanisms regarding the significance of various available cues of environmental variables.

This variation in learning rates has an important cautionary significance for the mosaicist. The processes by which dimensional and other forms of integration are achieved are not trivial or analytic. They demand significant computational resources. To put the point in its simplest terms: it requires new resources for representing conjunction to go from *red* and *round* to *red and round*. And in the absence of the requisite "neuronal substrate," this transition would have to be learned painstakingly.

VII. Zero-dimensional versions of MQ

As we saw above, Evans frames MQ as a problem about the perceptual representation of space (as opposed to shape). Although we disagree with Evans's view that the MQs posed above should always reduce to such questions, it is possible to ask versions of MQ closely related to the above that take spatial position and spatial relations as their targets. In other words, it makes sense to ask whether the raw unintegrated positional information given by one modality transfers to a second modality. For instance, we can ask zero-dimensional versions of MQ about the possibility of intermodal transfer for representations of such spatial features exemplified at single points:

Suppose we have two vibrators each fitted with a light that can be turned on independently of the vibrator. Both are placed on the newly sighted man's body, one on the palm of his hand and the other on his forearm. Now the room lights are switched off so that the man is sitting in the dark. One (and only one) of the vibrators and one (and only one) of the lights is turned on. He feels one vibrator and sees one light. Can he tell whether the active vibrator is lit up?

This version of the Molyneux problem requires the newly sighted man to identify the position of a tactual feature with the position of a feature identified by sight. Suppose he feels a vibration on the palm of the hand. His problem is to say whether a light is shining where the vibration is.

Similar zero-dimensional questions can be posed regarding the motor system's representation of space. Motor (and associated proprioceptive and tactual) representations of position are body-centred. So, if a foreign object (say a grain of sand on the inside of your glove) pushes against your finger-tip, it will tactually seem to be stationary, even if your hand and finger should move (either by your own agency or passively). Presumably this is because your tactile sense is linked to the motor system; it tracks the part of your body that you are able to move. In this instance, the positional framework of touch is different from that of vision.

Now, let Dr Molyneux ask:

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Suppose that a rubber hand is placed alongside a newly sighted man's hand. Let a flashing light be placed next to one of these. Now, suppose that both hands are synchronously stroked with a brush. Can the man tell by sight alone whether the light is next to his own hand?

This is a problem concerning the coordination of visual representation of external position and movement (of the brush) and tactile representation of bodily position and movement (of the stroking). We know that when this experiment is conducted with normally sighted patients, but with their own hand hidden from view, these subjects report that they feel the rubber hand being stroked (Botvinik and Cohen [1998]). In other words, these normal subjects would wrongly locate the flashing light relative to the rubber hand, and not relative to their own. This is an error of visuotactile coordination. Likewise, it is at least possible that in the rubber-hand MQ, the newly sighted man will lack the necessary visuotactile coordination, and therefore be unable to identify where the stroking is happening in the visual world.

Along the same lines, but with the opposite effect, consider this: If a spotlight suddenly appeared from some direction, would the newly sighted man immediately turn towards it? There is no evidence that this zero-dimensional MQ has a negative answer—for all that we know, this visuomotor coordination task is successfully performed. (Project Prakash workers report on no failure.) This seems to indicate that even the cross-modal locational task might not admit of a single uniform answer. It could very well be that cognitive systems work with multiple representations of space, and that coordination among these is piecemeal, not solved across the board. Visuotactile coordination may be subject to different parameters than visuomotor. (Evans [1985] makes much of the immediacy of sensory-motor connections.)

We can pose similar questions about relations in one spatial dimension obtaining between zero-dimensional points.

Two vibrators are placed on the newly sighted man's skin. A light (without vibrator attached) is also placed on his skin. All three are switched on. Can he tell by vision alone whether the light is in between the vibrators?

The newly sighted man is able to estimate distances by haptic touch. He is shown three non-collinear lights, A, B, and C. Can he tell by vision alone whether AB is a shorter length than ACB?

These lower-dimensional problems are about the intermodal transfer of position information and basic geometrical relations such as the triangle equality. As such, these versions of MQ are plausibly understood as concerning the intermodality of perceptual representation of space but not about perceptual representation of shape.¹⁸

VIII.A temporal version of MQ

Moving away from space-related versions of MQ, we now ask a version of MQ about time. A blind person is aware of the time it takes for things to happen. For instance, if two people speak, she is able to say who started and ended first. If she hears a rhythmic pattern, she can beat out the time with her finger. Now she is made to see. She sees two people speaking behind a sound-blocking window — their lip movements coincide with their speech sounds. Or she sees a rhythmic stream of light flashes.

Question: can she tell by sight alone which of the individuals spoke for longer or began/ended first? Can she beat time to the stream of light flashes?¹⁹

Again, it is possible to think about the question here in terms of a comparison between the resources available in different modalities for the integration of lower dimensional information (auditory qualities at zero-dimensional instants) into a higher dimensional (temporally ordered) representation. (Note that these MQs are audiovisual and visuomotor, rather than visuotactile as in the original.)

There are certain ways of thinking about the experience of time that suggest (given natural assumptions) that such temporal versions of MQ should receive positive answers

¹⁸ John O’Keefe and Steven Nadel [1978] argue that the representation of space used in memories of spatial layout derives not from information received through the senses, but in innate structures in the hippocampal formation. This might be taken to suggest that the perceptual representation of space is not modal at all, or that it is amodal/“premodal” (Matthen [2014a]) and that these zero-d MQs would get a ‘yes’ answer for reasons that have nothing to do with intermodal transfer.

¹⁹ Evans alludes to temporal MQ, though according to his wife and posthumous editor, Antonia Phillips, he was apparently of two minds about how to approach it (372).

either a priori or on the basis of some general principle that applies equally to all the cases being discussed.²⁰ The principles that have been proposed here are mosaicist in spirit; if you have access to information about every relevant instant of time, then you have access to higher-dimensional temporal patterns.

Some think that the temporal structure of our experience is inherited from the temporal structure of the events we experience.²¹ This implies that a flash seems to be before a bang just in case the flash precedes the bang.²² So, the events will always seem to occur in the order they actually occur—illusions of temporal order are impossible. As long as the temporal structure of the extended events mentioned above matches, as it is stipulated to do, there is no special problem of intermodal transfer over and above that of within-modality matching. On this reading, MQ must be answered positively if there is within modality recognition of a temporal relation.

Another route to a positive answer to temporal MQ goes through the Kantian idea that time is "nothing other than the form of inner sense" (A33/B49). According to this way of thinking, temporal experience is itself not proprietary to any single, externally directed perceptual modality—on the contrary, it is always discerned, introspectively, by self-awareness of experience itself.²³ Some extend this view to the experience of temporal relations, holding that experience of simultaneity/succession of two events just amounts to the simultaneity/succession of the experiences of those two events. This would imply an Introspective Reflection Principle for the perception of time, according to which two events are experienced as standing in temporal relation R if and only if the experiences of the two events stand in the temporal relation R. For example, the Introspective Reflection Principle

20 For example, Louise Richardson [2014] takes it as a datum that temporal MQs are unlike spatial MQs in meriting obvious positive answers, and attempts to explain why this should be so. What we say below suggests that the alleged datum is false.

21 See Ian Phillips [2008, 2011, and 2014].

22 More precisely, the claim should be that the timing of the sensory experiences matches the times that information about the flash and the bang are received. We see a distant flash of lightning before we hear the thunder that accompanies it because the sound arrives after the flash.

23 Barry Dainton [2014] ascribes something like this view to Locke, Berkeley, and (more tentatively) to Hume, as well as to Kant and Brentano; it is also endorsed by Richardson [2014].

would predict that a flash of light is experienced as occurring simultaneously with/one second before a drum beat if and only if the experience of the flash occurs simultaneously with/one second before the experience of the drum beat.²⁴

There is a wide range of evidence that threatens both these approaches, especially over periods so brief that experience of temporal relations must be extracted, some say “constructed,” by automatic or sub-personal processes. One simple illustration of the threat comes from the finding that subjects are unable to detect onset asynchronies between visual and auditory stimuli within roughly 250ms (Dixon and Spitz [1980]): within this window (whose breadth varies interpersonally), subjective simultaneity is susceptible to adaptation, and differs for different cross-modal combinations. Thus, subjects will experience two events as occurring simultaneously even though sensory information regarding them is received at different times.²⁵ Theoretical explanations of how experience of temporal order arises in these cases often appeal to processes that construct or reconstruct temporal order and could be prone to error. These explanations invoke a wide range of parameters and faculties, and there is no reason to expect that they would all operate the same way across modalities and domains.

The Introspective Reflection Principle is threatened even more directly by a class of “postdictive” temporal illusions, in which the experienced simultaneity/succession of two experienced events is mediated by the later experience. One such case is the flash-lag effect: when a moving object and a flash are visually presented simultaneously and in the same location, subjects report the flash as occurring later than the moving object (Nijhawan [1994]). David Eagleman [2009] reports an analogous cross-modal postdictive illusion. He began by adapting his subjects to a 200ms delay between a keypress and a subsequent flash, so that they experienced the two as simultaneous. When he then removed the delay in the next trial after adaptation, his subjects experienced the flash as preceding (hence, not simultaneous with) the keypress. *Prima facie*, these are cases in which the subject

24 Views in the vicinity of our Reflection Principle have been endorsed by Evans [1985: 373, n18], Mellor [1985: 144], Phillips (see note 18), and Dainton [2000, 2014]. Detractors include Daniel Dennett [1991], Dennett & Marcel Kinsbourne [1992], Rick Grush [2008], Geoffrey Lee [2014], and Matthen [2014].

25 Cf. Scheier, Nijhawan, and Shimojo, [1999]; Morein-Zamir, Soto-Faraco, and Kingstone [2003], and Spence and Squire [2003].

undergoes two experiences that are simultaneous, but, contrary to the Introspective Reflection Principle, she does not experience them that way.

There are, to be sure, strategies for reconciling these effects with the Introspective Reflection Principle. (See, for example, the "Stalinesque" interpretation of Dennett and Kinsbourne [1992], or the temporal smudge view of Phillips [2014].) Without taking any stand on the plausibility or success of these proposals, we want to make the more general point that answering the temporal MQ will depend on the particular, and potentially modality-specific, psychological mechanisms responsible for temporal integration.²⁶

These considerations about the temporal version of MQ offer lessons for the spatial MQs as well. Just as there is a non-trivial window of subjective simultaneity such that events picked out in same/different modalities and falling in that temporal region are experienced as temporally simultaneous, we can by analogy ask whether there is a non-trivial spatial window of subjective co-location such that events discerned by same/different modalities and falling in that spatial region are experienced as co-located (cf. the ventriloquist effect, 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).²⁷ This invites us to ask, further, whether visual domination over audition is relevant to MQs (in various spatial and temporal settings).

IX. A space+time, or four-dimensional, version of MQ

We said earlier that MQ raises general issues about integrating information over space and time together. And we have gone through various spatial dimensionalities in which these features are arrayed, as well as a temporal version and a version that probes how these features are learned. We conclude with a question about a feature exemplified by individuals at their location at different times. Motion is such a feature, and therefore is of special interest. Here is a version of MQ concerning motion.

²⁶ Of course, there is much more to say about these and many related results, the psychological processes of temporal integration that underpin them, and their significance for the philosophy of perception and the philosophy of time. For further examples and wide-ranging discussion, see Lee [2014] and Craig Callender [2017: ch 9].

²⁷ See Pick, Warren, and Hay, [1969]; Bertelson [1999]; Vroomen and de Gelder [2000, 2004].

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Suppose that two objects were shown to a man newly made to see, both moving from left to right, one continuously and the other in jumps. Could he tell by sight alone which is which?

We know that cortical motion blindness is an agnosia. Patients with lesions in the medio-temporal occipital cortex (MT) no longer see motion as continuous, but rather see it as a succession of discontinuous positions (Zihl, Von Cramon, and Mai [1983]). We don't know how soon after restoration of vision this visual area of the brain, which subserves the perception of motion as continuous, kicks in. We also do not know whether and how learning plays a role in the activation of MT. Consequently, the answer to this 4D MQ is unobvious, and certainly not a priori.

X. Conclusion

We take the foregoing to show that there is a variety of fruitful MQs, cast in a number of spatial and temporal regimes, that are about the transferability across modalities of information about spatiotemporal common sensibles, including spatial position, shape, temporal order, and change. We have argued, pace Evans, that these cannot all be reduced to questions about the existence and character of an inter-modally shared representation of space. We have also argued that it is wrong to assume that negative answers to MQ always trace back to negative answers to zero-dimensional percepts. Consequently, these questions cannot be answered a priori or by appeal to a single principle. Different MQs have different answers, within different sets of perceptual conditions. We have, however, outlined some organizing principles, based on similarities and differences among the modalities with regard to how they process information in various spatiotemporal dimensions. These organizing principles correspond to different types of obstacles that arise when the perceptual brain transfers information about features it represents in one modality to another modality.

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Caption list:

Figure 1: Do we have visual awareness as of a sphere in the scene depicted above, or only of a circular ‘plane variously coloured’?

Figure 2: Support for Mackie's interpretation of Locke. Newly sighted patients have difficulty recognizing occlusion in displays B to E. Some had difficulty identifying the longest curve in F, and none were able to resolve display G into faces of a cube. (c) indicates how a simple display resolves into three distinct shapes. The patients were unable to parse the displays on the top row of (e); the bottom row shows how a simple luminance-contrast algorithm performed. (From Ostrovsky et al [2009]; used by permission.)

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