THE PHYSICALITY OF SYMBOL USE

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We propose viewing the ways in which people use symbols and drawings as having an intrinsic physicality. When perceived as an extension of gesture-making, symbol use can give us insight into how symbol users experience the mathematics they're considering. To illustrate this, we apply this lens to examine selections from a video-recorded interview of a mathematician regarding one of his published papers. This results in several phenomenological characterizations of the mathematician's embodied symbol use that, in turn, offer potential insight into many instances of symbol use beyond this single case study.

Key words: Mathematicians, gesture, embodiment, phenomenology, symbols

Our main purpose here is to advance a perspective on symbol use informed by embodied cognition that is currently emerging in the field of mathematics education (Arzarello et al., 2009; Radford, 2009; Roth, 2004; Roth & Thom, 2009). In short, we choose to view symbol use as having an intrinsic physicality, which is to say that the meaning each of us perceives in symbols emerges from our actual and sensible-to-us interactions with them such as through drawing, erasing, pointing, changing body posture, and so on. We offer this perspective in contrast to a more commonly held one that symbols represent ideas via some kind of mental link that can be, but needn't be, demonstrated through bodily action.

Rather than detail the theory in full at the start, though, we think it may be easier to convey what we intend by showing you how a few particular instances of data appear when seen through this theoretical lens. In doing so we hope to share with you a vision of how symbol use is actually experienced in some very abstract domains.

Overview of Perspective

The data we'll use in this paper come from a video-recorded interview with a research mathematician, whom we'll refer to as "J". J is a topologist at a large doctorate-granting university in the southwestern United States. We interviewed J for an hour and fifteen minutes about a topology paper J had published ten years prior. The paper offered a geometric interpretation of a device known as the "6*j* symbol", which is involved in the addition of angular momentum ("spin") of quantum particles. A great deal of the interview involved J drawing analogies between quantum spin and its classical analogs, which J frequently depicted via rotating spheres.

The following screenshot was taken near the beginning of the interview. The video from which this screenshot was taken is a juxtaposition of two cameras' video data that have been time-synchronized. Thus they show the same scene from two different angles.

Figure 1 – Animating a Sphere

The transcript surrounding this moment is as follows: *"If you had a spin-, classical spinning particle like a ball, I mean its, its angular momentum is described by a vector…."* Mathematically, what J is describing here is the fact that any classical rotation can be described by a vector that is perpendicular to the plane of rotation and whose length indicates the speed of rotation. For instance, a top that's spinning counterclockwise could have its rotation represented by a vector that points in the direction of the top's handle (usually straight upward). In Figure 1, J attempts to convey this mathematical idea by drawing a sphere that we're to see as rotating, and he draws the rotation vector as an arrow coming out of the top of the sphere.

However, we'd like to draw your attention to his hand movement directly in front of the blackboard. After drawing the arrow coming out of the "north pole" of the sphere, J withdrew his right hand slightly from the board, held the piece of chalk he had been using so that it pointed roughly upward, and then twisted his hand about that piece of chalk counterclockwise as viewed from above. (The orange arrow in the right-hand image indicates this twisting movement.) In other words, he held the chalk as though it were the rotation vector for the sphere and then moved his hand in a way that conveyed the rotational motion of the sphere.

It seems prudent to ask why J did this. We aren't likely to come up with a definitive answer with such a small snapshot of data, but we can still develop something useful by exploring the question.

One way to attempt an answer would be to ask how J represents classical rotation in his mind. We could try to describe this in terms of some kind of mental construct; for instance, we might guess that J has a concept image (Tall & Vinner, 1980) for classical angular momentum that makes salient a mental picture that looks very much like the one he drew on the blackboard. We could test this hypothesis by asking J questions in a follow-up interview that should help to confirm or deny our guess, such as inviting J to share how he thinks about angular momentum when dealing with flat objects like spinning disks. At this tentative stage, this general approach would make us inclined to suggest that the reason J gestured as shown in Figure 1 is that he's trying to communicate a concept and is using his hands to help convey his concept image.

This is certainly a valid way to approach this situation, and there's probably something to be gained from it, but we'd like to suggest a perspective that's different from this and offers a different kind of insight. We posit that what J is doing here is actually *part of what he means* in his depiction of the sphere. It's not that his twisting of his hand expresses an idea he wants to convey, but that instead his hand rotation partially *constitutes* that idea by being a simultaneous practicing and conveying of the diagram's meaning as an embodied experience for him. For instance, the sense he has of the diagram depicting a three-dimensional sphere rather than a two-dimensional circle emerged from the spatiality of his hand movement. His proprioceptive sense of his hand's position around the imagined sphere is tied to the blackboard inscription by timing with respect to his spoken words, by proximity to the diagram, and by a repeated back-and-forth between indicating the drawing and doing hand movements similar to those in Figure 1. In doing so, he binds to the diagram the sense that he can reach out, grab, and rotate the sphere, giving the diagram its sense of implicit depth.

In fact, we suggest that the meaning J attributes to this drawing of a sphere is made up entirely of such perceptuo-motor activity. In other words, there is no “idea” of angular momentum that J “has” in a way that can be made independent of his embodied behavior. We can’t separate J’s gesturing from the meaning he perceives in the same way that we can separate a monitor from a computer; instead, it would be more like trying to separate a computer from its hardware.

We certainly acknowledge that there’s more to J’s understanding of the sphere he drew than this one particular gesture shown in Figure 1. However, we suggest that the impression that there are “hidden ideas” associated with this diagram comes from the existence of other perceptuo-motor activity that J perceives as pertinent to the diagram *but chooses not to act on.* For instance, it’s likely that J understands full well that were the sphere to be tilted so that the angular momentum vector pointed to the right, the sphere would instead be spinning vertically (i.e. counterclockwise as viewed from someone standing next to the blackboard to J’s right where the vector would be pointing). This understanding could be constituted in part by, say, a hand movement where J might “grab” a visualized sphere in front of the board with both hands and tilt it manually like one might tip a globe. Yet we don’t see J having actually performing any physical action like this, presumably because he did not see any point in enacting that part of his understanding of angular momentum at that particular moment. This “hidden” aspect of his understanding was therefore not acted upon because J inhibited that possibility even though he presumably recognized it on some level.

By reframing J’s movements this way, we no longer have to create formal models of what’s "really" going on in J’s mind. The mind is no longer viewed as a black box whose contents we need to model. Instead, we see J’s mind as distributed (Hutchins, 1999) across his bodily action and environment, both as acted upon (as in the case of the twisting movement in Figure 1) and as perceived as possible but inhibited (as in the case of tilting the sphere). This means we can gain insight into what shapes J’s phenomenological experience of his symbol use by carefully observing his bodily activity as he relates to the diagrams on the board (Erickson, 2004; Gallagher & Zahavi, 2008; Stivers & Sidnell, 2008). For instance, the moment depicted in Figure 1 shows a process of binding a physical movement to a diagram on the board in order to animate the diagram, so to speak, and part of that process in at least this particular instance requires that the animation occur very physically close to the diagram. This isn’t the only way J can bind movement to diagrams, and indeed at other times in this interview he shows a number of variations on how the movement can be linked to whatever is on the blackboard, but this one instance still provides us with some fair degree of insight about at least one way of animating and giving depth to drawings involved in higher mathematics.

Mathematical Regions

Another structuring pattern to J’s symbol use is with what we call *mathematical regions*. These are areas that occupy physical space in which J’s mathematical activity seems to occur. These regions appear both on the blackboard and sometimes in J’s peripersonal space when he turns or steps away from the board. Consider the following example (Figures 2 and 3):

Figure 2 – Defining a Mathematical Region

Figure 3 – Engaging in Another Region

The transcript is as follows: *"Maybe, you know, maybe you're just thinking about a system of interacting particles…. You need to do this kind of calculation…."* Here J is describing the need for the kind of spin addition he has written on the board when considering a system of interacting particles. Figure 2 shows J dropping both hands in synchrony (right before he says "system"). Figure 3 shows him stepping back, looking up at the board, and pointing with his left hand while he brings his right hand with the paper more toward his center line.

Although it's not depicted here, after the moment shown in Figure 2 J goes on to perform a number of gestures in the space between where his hands are in Figure 2. It's as though this initial gesture describes for J the boundaries of some kind of space in which he intends us to see this imaginary system of particles. His forward-leaning posture together with his gaze so obviously intent on something invisible between his hands seems to convey a vivid sense that something significant to him is going on in that portion of space. Having done so, he has created one instance of what we refer to as a mathematical region.

Just a few seconds later, though, J disengages from this space and engages with the blackboard. Figure 3 shows the result of this transition: J has stepped away from the space he had been using, straightens his posture, turns his gaze to the notation on the blackboard, and even uses his right arm and the paper it's holding to act as a kind of barrier between him and the area in which he had been working just moments before. Although his association with the blackboard material is at a distance (keeping the inscriptions in his extrapersonal space), the direction in which he has turned his body and gaze, as well as the shift in his spoken words, make it very clear that his perceptual and motor activity is engaged with the mathematical region on the blackboard now.

Notice how J's interaction with each of these two regions differ both from one another and from his style of interacting with the sphere in Figure 1. With the sphere, he stays close, keeping the drawing in his peripersonal space and alternating between gestures in front of the drawing and modifications of the drawing. With the region in space shown in Figure 2, J doesn't refer to specific written diagrams at all, instead outlining or representing objects or collections of objects and their actions via gestures. When J engages with the region of focus in Figure 3, he indicates it as though he's outside of it despite his attention being on it. These three examples help to illustrate the variety of ways in which someone can engage with mathematical regions to produce different effects. There are numerous other ways of engaging with such regions, too, and we'll detail some of them later in this paper.

At the same time, there are some remarkably stable patterns of interaction that seem to hold between these and other styles of regional engagement. One example is the defining of bounds so vividly depicted in Figure 2. This is far from an isolated case. Every time J creates a region, he does something to define its boundary, usually in one of three ways: create an embodied indication of its edges (as in Figure 2), use physical distance to distinguish between regions (as in J's having stepped away from the board to gesture as he did in Figure 2), and in the case of regions on the blackboard, he'll sometimes draw lines to indicate boundaries as in Figure 4:

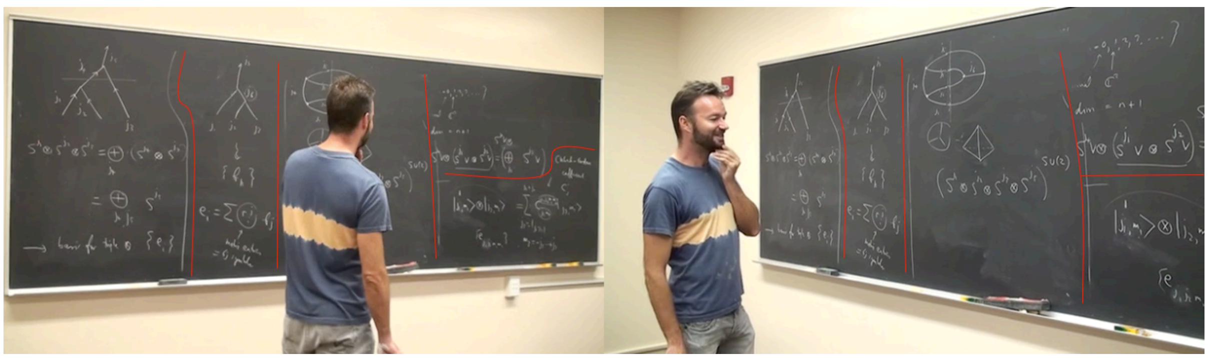

Figure 4 – Boundaries of Blackboard Regions

In Figure 4, we've outlined roughly where the boundaries between different regions on the blackboard are. You can see how the vertical boundary lines are actually drawn on the blackboard for the most part. Notice, though, that these drawn boundaries aren't firm: the "S" immediately above the juncture between the right vertical and horizontal boundaries is actually drawn across the vertical line. This is actually fairly typical, as there are many times where the gestures and diagrams J uses go beyond his predefined boundaries this way.

The horizontal boundary line from Figure 4 raises an issue that's worth commenting on. You might notice that there's just a tiny dash that represents that boundary between the rightmost regions. It's not drawn all the way across the same way the vertical lines are drawn all the way down. This indicates that although the drawn lines help to inform where J intends regions to be differentiated from one another, it's the *perception* of that separation rather than the physical division that's important to J. This is reflected again in the fact that J didn't draw any line at all to indicate the "kink" at the far right of the board. Instead, the awareness that the algebra in the top region don't relate to the words written at the far right comes from when J created each of these inscriptions and the manner in which he associated them with other regions. We'll discuss this method of defining boundaries in more depth a little later in this paper.

We find a reflection of this idea of mathematical regions in Husserl's (1913/1983) phenomenological description of a *horizon*:

> That which is actually perceived, that which is more or less clearly co-present and determined (or at least to some extent determined) is partly permeated, partly surrounded, by a *dimly given horizon of indeterminate reality*…. [Such] indeterminateness is populated with intuitive possibilities or likelihoods…. [A] never fully determinable horizon is

necessarily there. (Husserl, 1913/1983, p. 52. Italics in the original; the translation from German has been partially adjusted on the basis of Smith & McIntyre, 1982, p. 236)

In other words, a horizon is a sort of realm of possibilities that encompasses all the ways of perceiving and interacting with a given scenario that seem available to the individual in question. For instance, we can reach out and move a coffee mug immediately in front of us, changing how it looks to us as we do so. Alternatively, we can move ourselves, also changing the angle of perception. All the different ways we could move the mug or ourselves, together with the ways in which we anticipate this will change how we experience it, are included in the horizon of that situation.

Husserl emphasized how horizons can never be completely determined, which is to say that we cannot specify *all* the possibilities any one horizon contains. There are countless ways that we could move a coffee mug, for instance, and our interactions with other objects around the mug can also affect how we perceive the mug as well. Our perceptions can change even without explicit physical interaction: remembering how one got this particular coffee mug while on one's honeymoon can transform the way the mug appears by making its personal history and significance more salient.

Mathematical regions appear to be horizons of a sort. J creates a region in order to have a place to work with mathematical objects, which for him elicit a host of possible ways of their being perceived and manipulated. Most of these possibilities never get expressed or even reach consciousness, such as the matter of tilting the sphere as discussed in connection with Figure 1 earlier. So in this sense, these regions are areas within which J can choose to engage and navigate, but he cannot fully describe or define. It's therefore understandable for us to find that sometimes J's symbols cross the lines that describe the boundaries of the regions: those lines don't actually define the regions in a strict and precise way.

Diagrams Within Mathematical Regions

In keeping with our theoretical perspective, we need to describe the "mathematical objects" that populate these mathematical regions in a way that's grounded in perceptuo-motor activity. To keep the discussion focused, we'll restrict ourselves to the objects populating regions that are projected onto the blackboard – i.e. what most of us would like to say are the symbols J used in the course of the interview. To do so, we'd like to employ Charles Pierce's notion of a *diagram* (Stjernfelt, 2000, 2007) to describe these objects.

In short, a diagram in Pierce's sense is a symbolic representation that's amenable to transformations and experimentations that can reveal previously unnoticed properties of the referent.[1] This definition ends up capturing most inscriptions one usually thinks of as being involved in mathematics because it includes algebraic symbols: we can manipulate a line's equation given in point-slope form so that it's in slope-intercept form, which reveals something about the line that we might not have noticed from the initial presentation. We contrast this with symbolic representations like words: the written word "mathematics" isn't likely to reveal anything new to us about math no matter how we might rearrange the letters.

We'd like to highlight two phenomena we noticed about the ways in which J used diagrams as a result of our framework. First, there was a way in which J would engage with his diagrams a sort of imaginative "play". Think of how we treat photographs of people: it's perfectly normal to point at one and say "That's Aunt Norma" instead of "That's a picture of Aunt Norma." Both are fine to say, and we'd never actually confuse a picture of Aunt Norma with the person, but in the moment of use we see right through the image straight to what the image represents. In a very similar way, J would frequently "see through" his diagrams, treating them as though they were actually the objects that they represented. We saw this earlier when, in the situation shown in

Figure 1, J would refer to the collection of curves he had drawn on the blackboard as “a ball” even though they didn’t literally constitute a ball. Notice how this is naturally compatible with the perspective of J’s interactions with his diagrams as *constituting* the diagrams’ meanings rather than indicating an unseen but ontologically real referent.

Second, J frequently employed a kind of ambiguity as to whether he was dealing with a particular case or with a whole category of cases. We saw this too in the example of the sphere from Figure 1: even though J clearly drew a particular sphere with a particular rotation vector, it was just as clear that he was talking about rotation *in general*. Yet even though he was talking about general rotation, his gestural animation of the diagram made it clear he was engaging with the particular example of a sphere with a rotation vector pointing upward and spinning at a rate of at least two or three revolutions per second. This is reminiscent of when someone uses a particular quadratic equation as a stand-in for *all* quadratic equations as differentiated from, say, cubic or linear equations.

Embodied Paths

Armed with a description of the objects within the mathematical regions attached to the blackboard, we would now like to describe the main method by which J would connect these objects in order to provide context. We refer to this method as the travel along or indication of *paths* within and between regions. Consider the following example (Figure 5):

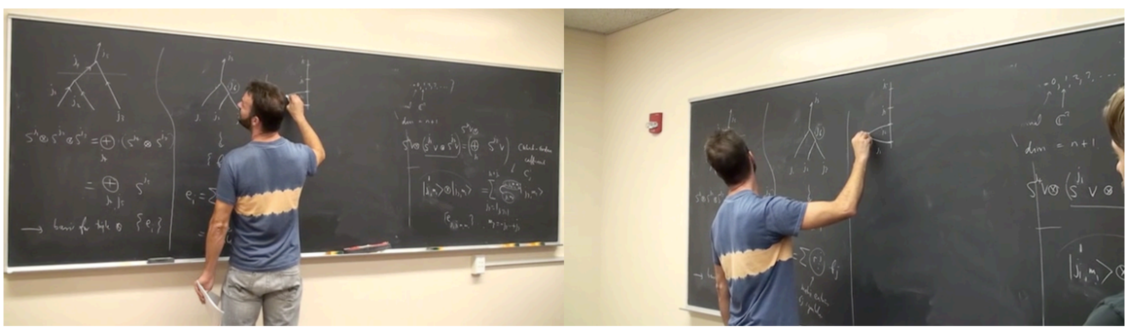

Figure 5 – Connecting Regions with Gaze

In the screenshot shown in Figure 5, J is in the process of creating a diagram that combines the tree diagrams directly to the new drawing’s left. He’s in the process of drawing the leftmost tree on the left side of the vertical line. You can see here how he vividly embodies that connection by keeping his writing hand engaged with the diagram currently being constructed but fixating his gaze on the leftmost tree diagram. His gaze switches back and forth between the new diagram and the older tree diagram as he draws this side. He then spends some time using gestures and words to highlight (Goodwin, 1994) the parts of the rightmost tree diagram that he wants us to attend to (see Figure 6).

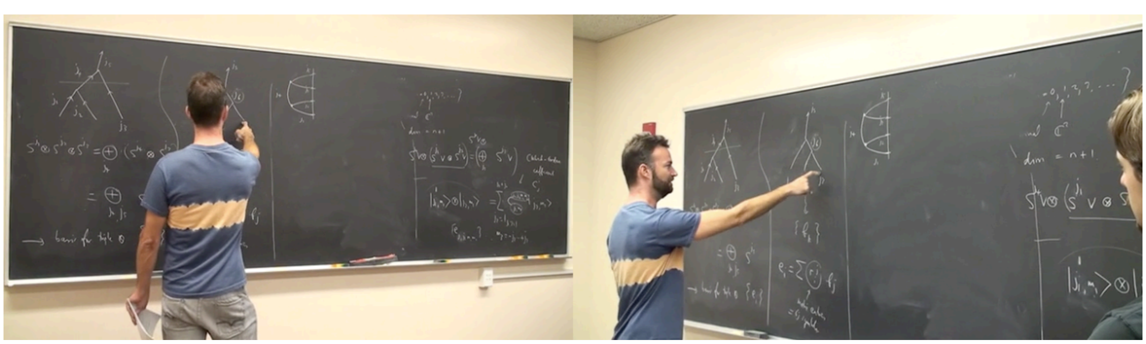

Figure 6 – Highlighting the Path's Contours

He finally repeats the gaze-connection process to bind the second tree diagram to the newest diagram, bringing the latter to completion (see Figure 7).

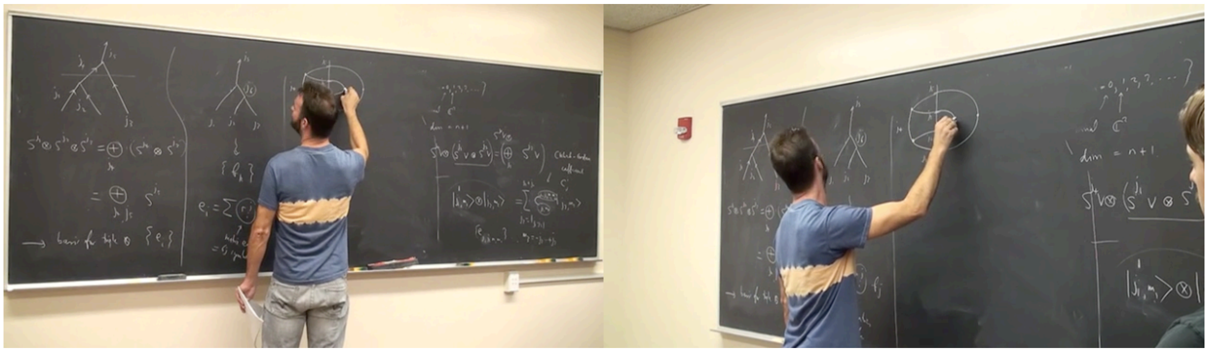

Figure 7 – Connecting More Regions

What we see emerging from this is that the meaning of that circular diagram in the third column is made up not only of J's interactions with that particular diagram but also emerges from the way he connects it to these other two diagrams in two other regions. J's intent appears to be for us to see the circular diagram as built up from aspects of these tree diagrams, and in order to convey that J puts a lot of effort into explicitly connecting all three regions. Yet he does not merge them. Instead, he describes via embodied enactment how one should perceptually travel through and between these regions in order to make the intended meaning of the newest one salient.

There are many different ways in which paths appear, and their various forms change the way meaning is intended and, presumably, experienced. In the above example, J went back and forth between the newest diagram and the older ones repeatedly while constructing the new drawing. This differs significantly from the way he later redrew the circular diagram in what he referred to as a "Mercedes badge" (see Figure 8).

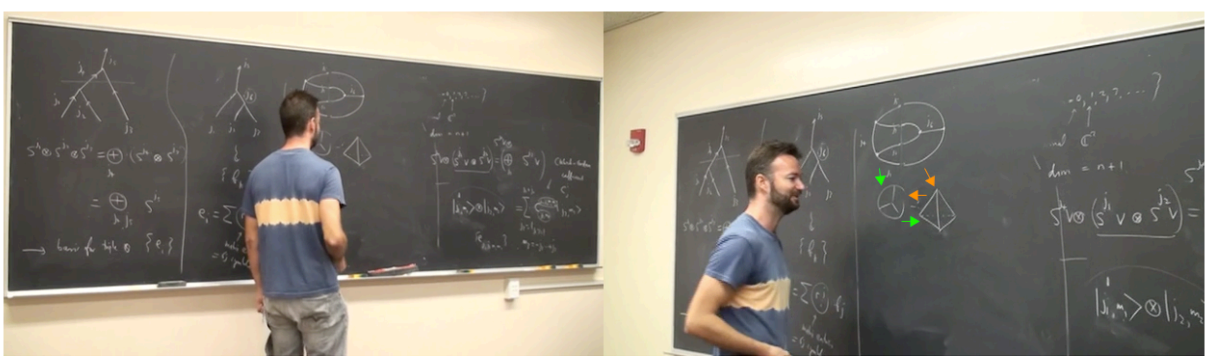

Figure 8 – Paths Within a Region

In Figure 8, J has drawn three different diagrams, namely the one he was working on in Figures 5-7, a drawing of a tetrahedron, and a Mercedes badge consisting of a circle with three equidistant radial lines within it. J seemed to intend the Mercedes badge to be a redrawing of the large circular diagram and indicated the latter via gestures only once right before drawing the badge. In this sense the meaning flows from the large diagram to the badge *but not the other way around*. In the course of the story J is telling here, the badge *replaces* the original large diagram. This has a very different quality than the relationship between the large drawing and the two tree diagrams described earlier: the back-and-forth embodied travel between them created an association of meaning between them that allows us to understand them as *different yet related* mathematical objects.

Embodied paths aren't necessarily formed in the order that the symbol-user intends them to be followed. The orange arrows in Figure 8 indicate the order in which J drew the diagrams in that central blackboard region. However, the green arrows show the path of meaning that connects them: the Mercedes badge is a rewriting of the large diagram, and one gets the tetrahedron from that badge by straightening the badge's edges and lifting its center out of the blackboard. One can certainly understand that by understanding the mathematical context, but in this case the (green) path was actually traced out via J's gestures and gaze. This is akin to how someone might draw a map and then point to indicate the route within that map one should take.

Furthermore, paths needn't be tied to the board. J demonstrated this in the time surrounding Figure 2 when he disengaged from the region on the blackboard, created and worked in a region made up of gestural objects, and then (in Figure 3) stepped back to return attention to the blackboard region. The context in which to understand his intent requires traveling off the board into a region of invisible objects and then returning to the board with a slightly different perspective for having gone on this trip. This, again, emphasizes the point that the meaning of a diagram emerges from an incredibly wide array of embodied activity.

Juxtaposition of Regions

One last embodied phenomenon we'd like to point out from this episode is that of juxtaposition of mathematical regions. At times, J would make a point by comparing and contrasting different mathematical regions *from the outside* instead of engaging with them and animating the diagrams within.

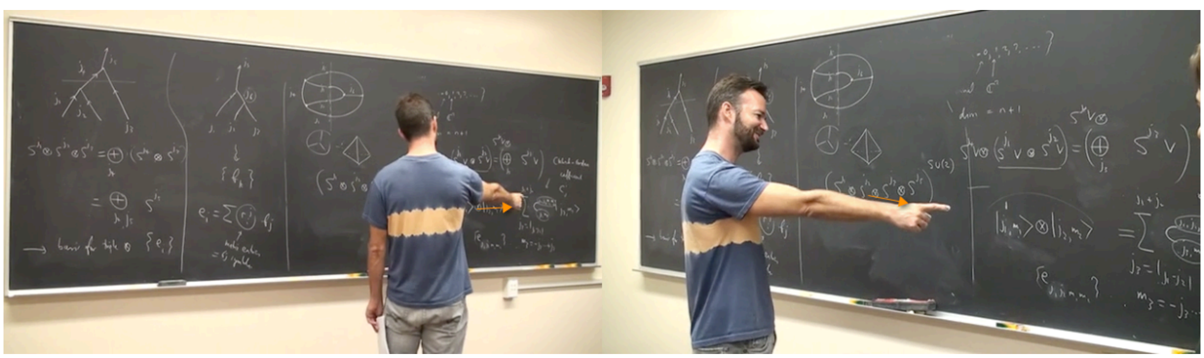

Figure 9a – Juxtaposing ("matrix-based calculations")

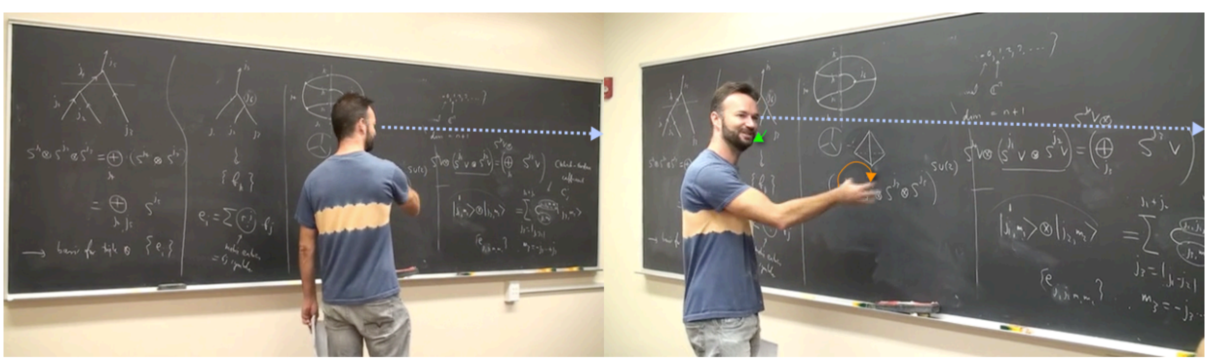

Figure 9b – Juxtaposing ("conceptual idea")

Figure 9 shows J juxtaposing two regions. Here he says, *"…I hate matrix-based calculations like this. I think it's just ugly! And, uh, you know, having a kind of* *conceptual idea of what you're, you're doing is much, much more useful to a mathematician."* He points at the "matrix-based calculations" in Figure 9a, sweeping his hand side to side to indicate the whole region. He then backs up away from the board for a moment and then moves closer to it to wave his hand around circularly as shown in Figure 9b.

The main point we'd like to highlight here is how J seems to place himself *outside of* the regions he's indicating. Rather than traveling back and forth between specific diagrams in the two regions, he seems to want us to take each region as a whole object to be considered. He still focuses his attention on specific diagrams within those regions that seem to be representative of them in the context he's describing (namely the bra-ket notation in Figure 9a and the tensor product in Figure 9b), but he clearly doesn't want our attention to lock onto those diagrams to the exclusion of the rest of the region. We see this in the imprecision of his gestures: the waving back and forth of his pointing in Figure 9a and the open-handed circular movement in Figure 9b offer a kind of ambiguity that bespeaks Husserl's (1913/1983) horizons of ephemeral boundary.

Concluding Remarks

Throughout this paper we have attempted to share an alternative to viewing symbol use as references to unseen conceptual referents. This alternative is based on perceiving the physical ways in which symbol-users interact with the symbols in question as actually constituting the meanings of those inscriptions. This theoretical perspective allows us to get insight into how the subject navigates symbolic meaning by observing how he bodily engages with his environment.

We would like to emphasize that we intend this not as a critique of reference/referent approaches, but instead as a powerful alternative that provides a different kind of insight. In particular, we usually find that this kind of analysis helps us to understand by what means a subject structures his or her experience of and approach with the mathematics at hand. For instance, the fact that embodied path travel appears to be different from external juxtaposition of regions suggests a particular difference in how thinking involving each of these approaches is experienced by the subject, which would be a very challenging observation to make if we were trying to discern, say, J's schemas of the various mathematical ideas involved.

As with more cognitivist approaches, the value of a case study of using this theoretical lens is in the insight it can provide us on beyond the case in question. We've elaborated on the phenomenological constructs that we have – namely mathematical regions, blackboard inscriptions as diagrams (Stjernfelt, 2000, 2007), embodied paths, and juxtaposition of regions – because these appear in a wide variety of cases. Having noticed these phenomena, we can now see it in the data we've collected on many other mathematicians and also in the symbol use of non-mathematicians. Our hope, in part, is that you too will find your vision of symbol use affected by noticing these phenomena when and where they occur.

We also hope that you recognize that the *kind* of insight that emerges from our theoretical perspective is very different than one of, say, exemplifying a particular student's understanding of a derivative in terms of mental schemes. The latter most certainly can give us some insight into matters such as why some students make the reasoning mistakes that they do in calculus classes, and we think there's most definitely value in such approaches. But the embodied approach we're attempting to share here can help us to see more general phenomena about how mathematical experience is structured and created, which can in turn help us to understand mathematical teaching and learning in new and potentially powerful ways.

Endnote

(1) Technically, the description of a diagram that we're using here is actually Pierce's definition of an *icon*. Diagrams are one of three sorts of icons, distinguished from

the other two by the fact that it captures “a skeleton-like sketch of relations” (Stjernfelt, 2000, p. 358). There is potential value in emphasizing the diagrammatic rather than just iconic nature of J’s inscriptions, but in the interest of brevity we’ve omitted that analysis.

References

Arzarello, F., Paola, D., Robutti, O., & Sabena, C. (2009). Gestures as semiotic resources in the classroom. *Educational Studies in Mathematics, 70*(2), 97-109.

Erickson, F. (2004). *Talk and Social Theory.* Cambridge, UK: Polity.

Gallagher, S. & Zahavi, D. (2008). *The Phenomenological Mind.* New York: Routledge.

Goodwin, C. (1994). Professional Vision. *American Anthropologist, 96*(3), 606-633.

Husserl, E. (1913/1983). *Ideas Pertaining to a Pure Phenomenology and to a Phenomenological Philosophy: First Book.* Hingham, MA: Martinus Nijhoff Publishers.

Hutchins, E. (1999). *Cognition in the Wild.* Cambridge, MA: MIT Press.

Radford, L. (2009). Why do gestures matter? Sensual cognition and the palpability of mathematical meanings. *Educational Studies in Mathematics, 70*(2), 111-126.

Roth, W-M. (2004). What is the meaning of “meaning”? A case study from graphing. *Journal of Mathematical Behavior, 23*, 75-92.

Roth, W-M. & Thom, J. (2009). Bodily experience and mathematical conceptions: from classical views to a phenomenological reconceptualization. *Educational Studies in Mathematics, 70*(2), 175-189.

Tall, D. & Vinner, S. (1980). Concept image and concept definition in mathematics with particular reference to limits and continuity. *Educational Studies in Mathematics, 12*(2), 151-169.

Smith, D. & McIntyre, R. (1982). *Husserl and Intentionality.* London: D. Reidel Publishing Co.

Stivers, T. & Sidnell, J. (2008). Multimodal interaction. *Semiotica, 156-1/4*, 1-20.

Stjernfelt, F. (2000). Diagrams as centerpiece of Piercian epistemology. *Transactions of the Charles S. Pierce Society, 36*(3), 357-384.

Stjernfelt, F. (2007). *Digrammatology: An Investigation on the Borderlines of phenomenology, ontology, and semiotics.* Dordrecht, the Netherlands: Springer.