Drawing and Visualisation Research

Published in *TRACEY* | journal
Thinking
December 2014

www.lboro.ac.uk/departments/sota/tracey/
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Special Edition:
Drawing in STEAM

USING SKETCHING: TO THINK, TO RECOGNISE, TO LEARN

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I would like to talk about how it is possible to think with our body and other things. I choose this topic in a workshop on drawing because sketching can, at times, be a way of interactively thinking with pencil and paper – of thinking with things. This process is not unique to drawing, and is, in fact, representative of interactive cognition more generally. The first thing I discuss, then, is this key interactive strategy: the process of creating, projecting and creating structure. I show why projection – which is a process of adding extra features or structure to an external thing that anchors and supports it – can be more powerful than imagination alone.

The second thing I discuss is how the principles underpinning certain types of drawing, in particular, the principles of lithic illustration (Addington 1986) can help paleo-anthropologists decide whether knife-shaped stones are human made or nature made. The act of drawing, when done right, can help anthropologists distinguish a 'knapped' chip mark from an eroded one. Because drawing, albeit in this technical way, partially *simulates* the very process of knapping and chipping stone, it provides paleontologists with a physical way of seeing the way the stone was made. In this case, the act of drawing serves to manage attention so as to produce professional vision.

The third thing I present comes from the dance world: how dancers sketch and 'mark' phrases. When working quickly to learn a dance phrase, dancers will often say they first 'sketch' the movement. This sort of sketching uses the whole body as instrument and of course is ephemeral; it leaves no trace. Later, when practicing, after initially mastering the phrase, they use a related process called marking. When marking, a dancer creates a simplified model of the full movement. It is like a physical sketch but the dancer now knows the phrase much better and uses this simplified version to practice specific aspects. This simpler movement requires less energy, it is less emotional, and it is typically smaller. Marking is a way dancers think with their bodies. They use their bodies as both tool and clay, as instrument and medium.

1. Projection

Prove this claim:

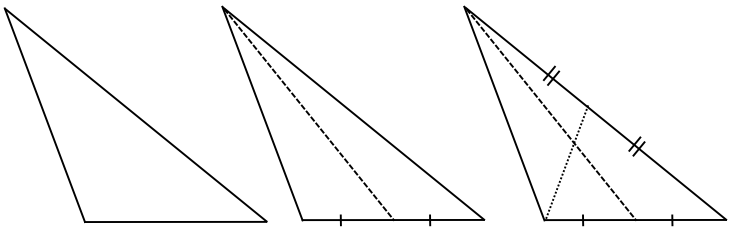
> *All 3 medians of a triangle always intersect at a single point.*[1]

How would you proceed? Most people will reach for a pencil and ruler to solve this kind of question. Why? Because it is too hard to do all the thinking and imaging entirely in their head.

[1] A median is the line from a vertex to the midpoint on its opposite side.

This reveals a key interactive strategy: when you have a problem, if you can solve it in your head, you go ahead and do so. If you can't, though, you typically do something on paper (or with objects nearby, or with tools, models and so on) to help scaffold or enact your thinking.

Look at figure 1. Returning to the median problem, the first thing you probably will do is to create a triangle, as in 1a. The next step is to concentrate on the median. Perhaps you will make one of those mentally rather than drawing it. This mental projection is shown in 1b; because it is projected it is shown here as a dotted line. The other two medians have yet to be constructed. Looking at figure 1b are you able to project both these medians on top of your first projection? This is the test you need to do to probe your intuitions about whether three medians intersect in one point.



1a. 1b. 1c.

FIGURE 1. 1A SHOWS A DRAWN TRIANGLE. IN 1B THE DOTTED LINE REPRESENTS A PROJECTED MEDIAN. IN 1C THE SECOND MEDIAN IS MENTALLY PROJECTED TOO.

If you actually try to do three projections some of you will succeed, but most will not. For me personally, I can project a total of two lines, as in figure 1c, but I can't do a third. I am not confident that I can keep in mind precisely where the other lines intersected, at least precisely enough to be sure my third projection runs exactly through the same point. So I reach for a ruler, and begin to draw all three medians. Once I have two in place I may or may not need to draw the third, depending on how accurate I think my projection of the third median is.

This interactive process of creating structure in the world – that is, drawing a median – then projecting onto it – that is, imagining a median drawn onto the current drawing – then creating more structure, then projecting onto it … this strategy is how we work much of the time: we do what we can in our heads and when we can't do more we create structure outside to enable us to continue projecting. It is a fundamental interactive strategy.

Project → Create → Project structure

As is clear from our simple geometric example projection gets more faulty the further out you go. It becomes harder and harder to keep all that stuff reliably in your mind. By externalising, we convert mental projection, mental stuff, into a form that is more useful because now it is outside. This cycle of thinking by projecting onto the world, then creating

external structure, and projecting some more, lets us go beyond what we can do in our heads alone. By creating things that are stable and persistent outside we are able to compensate for the limits of our imagination.

Although projection is similar to pure imagination it is also different in important ways. In imagination a triangle, for instance, has no specific size. Is it one inch or one meter? Does it even make sense to ask? But when you project a line or a triangle, there is some external structure that supports or anchors the projection. This means that the structure or process you project must have a specific size, and it must be assigned a specific location outside, else it won't anchor correctly to the thing you are looking at. In this respect, projection is like drawing. When you draw a median, as in figure 1b, the line you make is very specific to the triangle it sits in. When you project a median onto that triangle, you are similarly constrained. Your projection has to fit the triangle; it is spatially anchored on that external physical thing.

To test if people were better at projecting than at imagining we performed a simple experiment based on tic-tac-toe. We wanted to see if they would do better when they projected structure onto something rather than imagining the whole thing.

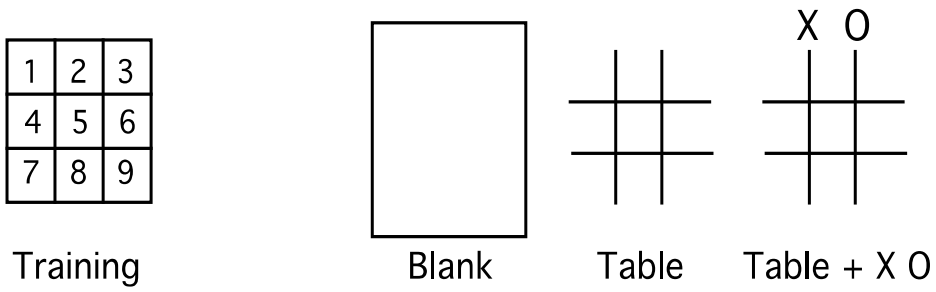


FIGURE 2. WE TRAINED SUBJECTS TO PLAY TIC-TAC-TOE BY CALLING OUT THEIR MOVES USING THE CELL NUMBERS AS SHOWN ON THE LEFT. OPPONENTS ALSO CALLED OUT THEIR MOVES. ON THE RIGHT ARE THE THREE CONDITIONS OF THE EXPERIMENT: BLANK PAGE FOR THE PURE IMAGINATION CONDITION, TABLE FOR THE PROJECTION CONDITION, AND TABLE WITH X AND O FOR A VARIANT OF THE PROJECTION CONDITION.

We trained subjects to play tic-tac-toe by calling out numbers. If a subject wanted to put an X in cell 9, they would call out 9; the experimenter would reply by calling out a number corresponding to the cell (s)he wanted to place her O onto, and so on. The cell grid and the stimuli we used are shown in figure 2. There were three conditions; in the imagination condition, subjects were given a blank piece of paper. Some subjects preferred to close their eyes. In the projection condition, they were given a piece of paper with the standard tic-tac-toe table, or grid, on it. Obviously, they were not allowed to mark the table they had in their hands. In the third condition, they had the same table, but now there was an X and an O above it.

What we found surprised us. We expected people to do better with the table (grid); we predicted that projection would be better than imagination because we thought that having a table would make it easier to form a mental image of the current state of the tic-tac-toe

game than having to imagine the whole board. We thought the grid would scaffold projection, making projection a simpler, less demanding task than imagination. But, in fact, subjects, overall, did not benefit from having a grid. The grid did not facilitate memory or imagery, since people did not play better in the grid condition. See figure 3 for the results showing that 'all subjects' (n=21) perform about the same in all conditions.

As part of the study, however, we had our subjects complete a pretest to determine how effective they were at visualising. This pretest consisted of questions requiring subjects to describe how well they visualise, or image in their mind's eye, specific visual situations.[2] For instance, a situation to visualise might be a scene at the beach where a middle-aged man has just inserted a large umbrella into the sand and it is casting a pleasant shadow over his two children, each of whom is sitting on a towel.

Once we divided our population into strong and weak visualisers based on the information from this test the data became far more interesting. We found that strong visualisers perform better overall but they gain nothing of significance when using the table (the normal projection condition). Weak visualisers performed less quickly overall; they derived a tiny bit of improvement from the table, but, as with the strong visualisers, none of these differences were large or statistically significant.

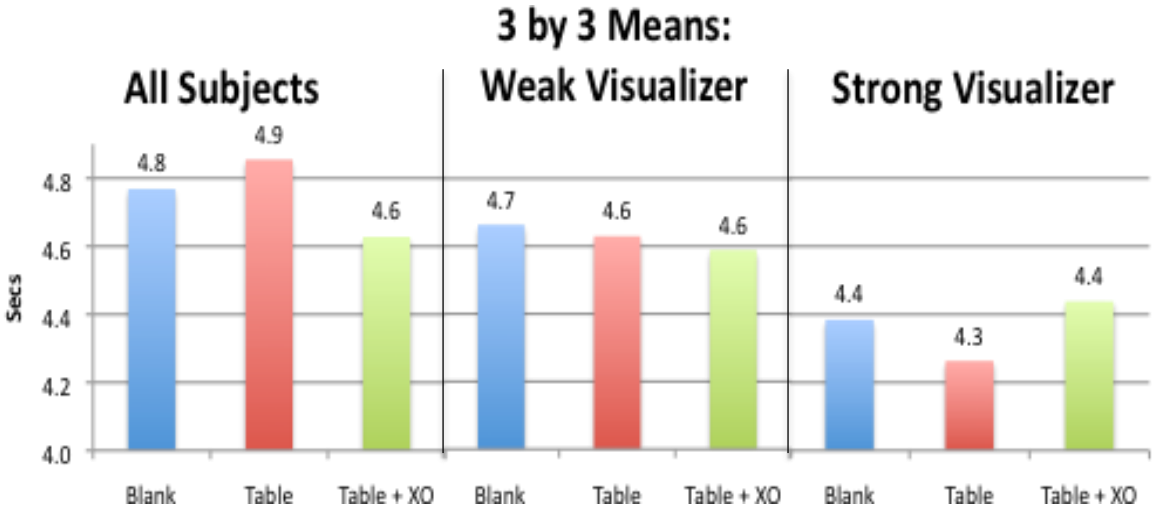


FIGURE 3. OVERALL SUBJECTS DID NOT BENEFIT FROM LOOKING AT AN EMPTY TIC-TAC-TOE TABLE. THE BEST VISUALISERS WERE BETTER THAN THE WEAKEST ONES, AND BOTH STRONG AND WEAK BENEFITED A LITTLE FROM THE GRID, BUT NOTHING WAS SIGNIFICANT

[2] The name of the test is the vividness of visual imagery questionnaire2 (VVIQ2).

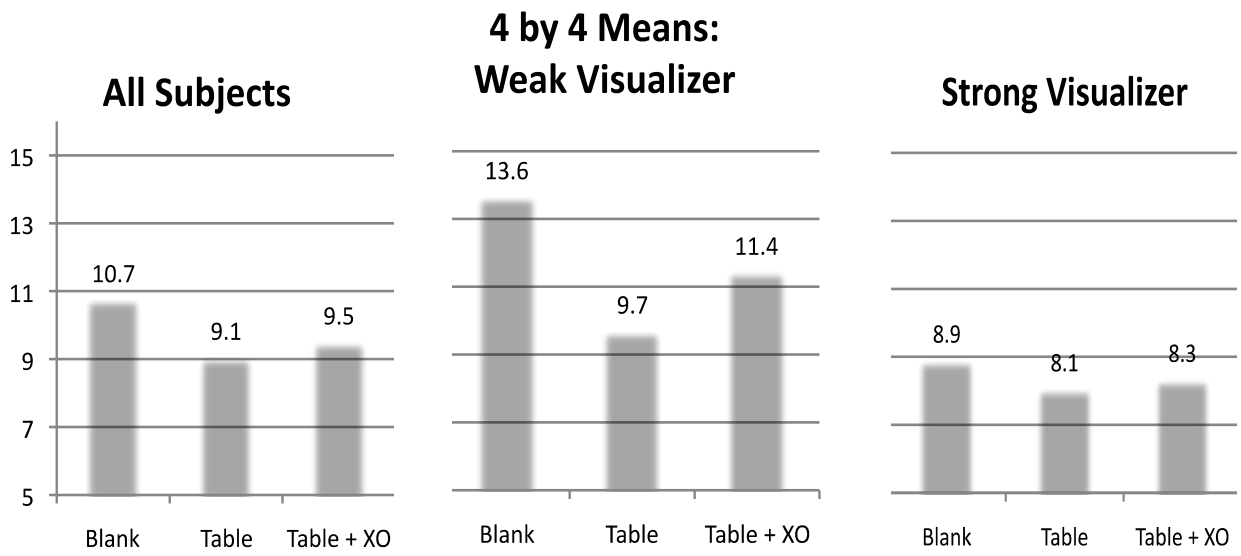


FIGURE 4. IN THE 4 BY 4 GAMES SUBJECTS DID PERFORM SIGNIFICANTLY BETTER WITH A TIC-TAC-TOE TABLE. BUT THOUGH STRONG VISUALISERS BENEFITED ALSO FROM THE TABLE THEY DID NOT YET REACH STATISTICAL SIGNIFICANCE. WEAK VISUALISERS HOWEVER DID SIGNIFICANTLY BETTER IN THE TABLE CONDITION.

We next ran the same stimuli for a larger version of tic-tac-toe, a 4 by 4 table, where the goal is to achieve four in a row to win. Here the results were more as we expected. As shown in figure 4, all subjects perform better when they have a tic-tac-toe board to look at the table or grid condition. Weak visualisers perform significantly slower in every condition than strong visualisers but they benefit much more from the scaffold provided in the table condition. The third condition, a table with an X and O above it, also improves performance, but now it is clear that the X and O symbols diminish the usefulness of the table; they are slight distractors. Strong visualisers, too, benefit from the table, more than in the 3 by 3 game but their improvement here is still not yet significant; it only trends toward significance. Evidently, the task has to be difficult enough that it cannot reliably be done in the head. Whether a 3 by 3, 4 by 4 or even 5 by 5 game can be done in the head is relative to a subject's abilities. Hence, it was predictable that weak visualisers would get more from the scaffolding a table provides. We would also predict that in a 5 by 5 game, where the game is challenging even for strong visualisers, the table condition will finally dominate significantly for all players, weak and strong alike.

Despite the apparent cognitive value of a table many of our subjects reported that it was unhelpful, even getting in the way of mental play. Evidently, there are times when imagination is better than projection. There must be a cost to mental action of placing an image or symbol somewhere in the visual field. This cost appears as important when the mental task is not too challenging. At such moments the cost of anchoring a mental image outweighs the benefits. But as the task increases in difficulty imagination becomes unreliable and the benefits of external structure can be appreciated.

2. Lithic illustration

The second phenomenon I will consider has to do with the power that drawing exerts over perception: it helps direct the eye to what is most relevant. In Paleoanthropology the received method to determine whether a given paleolithic stone is a cutting tool or just an eroded stone that resembles a cutting tool, is to sketch the stone. The 'how to' of sketching lithic stones has been codified in a set of principles of 'lithic illustration' (Addington 1986). Good archaeological illustrators use these principles. But so do practicing Paleoanthropologists. With pencil in hand a person can feel the physical 'problematic' the tool cutter faced. If the problematic of tool making does not feel real the stone was the product of natural erosion. In a sense the need to draw the tool according to lithic principles serves as a proof that the stone is human made. These principles reveal the "scale; the pattern, sequence, direction, and force of blows to the stone; the bulb and platform of percussion; areas of retouch, snapping, and truncation; areas of grinding, battering, or abrasion; fractures caused by heating; the effects of materials; and pitting and sickle sheen." (Lopez 2009) Features of the stone that might be confusing such as embedded fossils, variegated colouration, patina, seams, banding, and crystallisation are left out of the drawing.

The implication is that expert illustrators, when practicing their craft, are forced to scrutinise stones in a special way. They coordinate hand and eye to interactively probe the stone to reveal knapping related features. The need to draw certain lines drives perceptual inquiry. Attention must be managed, and arguably, without the need to sketch, without the presence of the emerging sketch – an external structure that the illustrator is creating – attention would not be managed adequately. Of course, this is an exaggeration. Illustrators have professional vision (Goodwin 1994) and so can see elements of what they would draw without actually drawing. But in drawing, the process of making lines and ensuring they are spaced revealingly, is itself a process that simulates knapping. Using a pencil to draw a curve is physically related to using a knapping stone to flake a chip off a stone. It physically simulates knapping. So, the drawing process can help the illustrator walk through the history of the axehead's making. The drawing is an external representation, and the process of making this representation is a powerful method for structuring attention. It helps the illustrator to figure out what an artifact is by studying 'the details of its making' (ibid).

3. Marking

The third phenomenon to consider here is a form of practice in dance called 'marking'. It bears on the embodied nature of drawing because first, it is often thought of as a type of sketching itself, albeit with a body. In a sense marking is sketching in three dimensions and motion. Second, and more importantly, marking ties in with our theme of projection and

creation and our theme of 'sketching' as a tool for managing attention and working out ideas.

What is marking? The derivation of the term comes from the phrase 'marking in time', a process where dancers run through the steps and transitions of a phrase, preserving duration but compromising on form. Professional dancers begin each day with a few hours of warm up exercise and then are expected to work for another five hours. No one can be expected to practise with full energy and full intensity the entire seven hours. Injuries might occur. Accordingly, when practising, dancers often work on smaller, less energetic versions of their phrases. This marked form looks like a simplified and imperfect model of the real phrase.

To an outside observer watching a dancer execute this simplified form, the look on their face makes it seem as if the dancer simultaneously has in mind the more complex, more energetic phrase they are marking. They seem to be doing one thing in the world and another in their head. In interview, dancers confirm this very claim. They say that when they mark they see the real thing or some specific part of the real thing in their head.

This raises an obvious question: how can dancers get anything *more* from marking than from mental simulation? We know that mental simulation can improve performance; it is a recognised form of practice. We know also that marking is essentially moving in a similar but nonetheless wrong way. So what extra can moving the body add to the good things that come from mentally simulating moving in the right way?, Indeed, why bother to move the body at all? Why not just sit still and mentally simulate the phrase?

To learn whether marking adds something beneficial to mental simulation, to show, in other words, that it is not just a movement epiphenomenon, like muttering when you think, or jiggling when you are nervous, we did a study that involved teaching three new phrases to ten super-expert dancers, all from the Wayne McGregor | Random Dance Company. The dancers were broken into three groups. One group practised their phrase by lying on the ground and mentally simulating it; another group marked it; and a third group practiced it by repeatedly doing it full out.

The procedure was this. All three groups were taught a phrase by a choreographer. After learning the phrase during a ten-minute period, each dancer was graded individually on how accurately they performed the phrase. Next, each group practised the phrase for ten minutes, using their assigned method: the three conditions of practicing full out, marking, or mental simulation. At the end of that practice period each dancer was graded again, and we calculated how much each had improved. The size of this improvement showed the benefit of practicing in a certain condition. Each group then changed its practice condition and was taught a new phrase. Accordingly, if group one marked when practising phrase one, they now practised phrase two by dancing it full out, and then later they would practice phrase three by mentally simulating the phrase.

When setting up the experiment we were hoping to find that marking was a more effective method of practice than mentally simulating a phrase while lying on the floor. That was certainly true, we did find that both marking and full out practice were better than mental simulation. But far more interestingly, and to our absolute surprise, marking was better than full out performance by a small but significant amount in most dimensions of assessment.

What does this show that is relevant to drawing and sketching? The conclusion we drew is that marking mediates thinking about the target – that is, a dance phrase – in a way that helps a dancer focus attention and project thought. When a dancer marks, it is easier for them to home in on timing or technicality or ordering of steps than when they try to work on everything at once, as they would were they practicing full out. Like making a lithic illustration, a dancer, by marking, can bring specific aspects of a complex thing into focus. First this curve, then this step. So marking drives attention to aspects of a structure or process in arguably the same way that having to draw a lithic stone drives attention to specific aspects of the stone. Marking, drawing and sketching focus attention.

Marking also teaches us something about the project create project cycle. One possible explanation of why marking helps dancers so much more than mental simulation is that the movement of the body may serve as a support for projection. This point is significant because in mental simulation dancers can also focus on specific aspects of a phrase. They can do the equivalent of sketch in their imagination. The reason they do not get the same benefits as marking is precisely the question at issue.

The answer, I believe, is that whereas imagination proceeds without any physical feedback, marking is a physical process that can help a dancer attend to things that receive immediate feedback. Many dance movements rely on playing with physical things like weight, force and rigidity. Without feedback from the body it is hard to imagine accurately what one needs to watch out for when falling, leaping, catching another, stiffening an arm.

To sum up, marking is a physical process in the world, like drawing and sketching. As such it serves to externalise; it provides a substructure or scaffold, like the grid in tic-tac-toe, that a subject can project onto. The reason a dancer can probe more deeply into a dance phrase by marking than by mental simulation is that marking provides the dancer with the right support to see the features (s)he needs to see. Imagination is more limited. It is virtually impossible, for example, to imagine the precise tipping point of a body. There are too many factors. But it is easy to feel that point when one is about to topple. Marking provides the basis for this sort of projection. It adds to imagination. Marking may offer the perfect compromise between doing it in the head and the world.

4. Conclusion

Drawing and sketching, like other forms of externalising thought, are often seen as aiding thought by providing a persistent structure to build on. In considering the interactive strategy of projecting-creating-projecting structure I emphasised that the value of persistence is as much to provide a kicking off point for the future as it is to record the past. Projection is an understudied process, and yet it may be at the heart of much human thought. It is easy to see its value in geometric problem solving, but it is general enough to be seen as a process throughout our active probing of the world.

This idea, that projection is an active or enactive process where we first impose structure and then typically create some aspect of the structure we just imagined, ties to lithic illustration. When paleoanthropologists draw a stone to structure how to scrutinise the stone their act of drawing can help them see the lines of 'making' in the stone. The physical action of drawing may make it easier to see how an early hominid knapper chipped away at a stone. As before, projection is a process that lets one see more than is there. It adds something. The lesson of lithic illustration is that the process of projection can be structured by rules of drawing. How to project the right structures can be taught and regulated.

The last phenomenon I discussed – marking in dance – pressed the idea that projection is more powerful than imagination because it can harness physical attributes like rigidity or stability that are only imperfectly available in imagination. Marking is a provocative case, halfway between inner mind and outer body where we do things in the body for their immediate effect on imagination. We dynamically shape the body to facilitate projection, which is essentially a way of shaping imagination.

It is dangerous to say that we can think better in the world than we can in imagination alone. Our discussion of projection suggests that the dichotomy is illusory. Whenever we act we facilitate projection; projection is just imagination tied to external structure. The challenge is to find better actions since these will lead to better projection – better imagination.

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