CHAPTER 8

The drawing experiments

Introductory

A short account has already been given of my coffee room meeting with Bill Phillips and how this led to my involvement in experimental research. Here its consequences are elaborated upon. A main conclusion to come out of the studies that will be described are that it is difficult to distinguish between "drawing what you know" and "drawing what you see". The reason is that the conscious awareness associated with the word "seeing" is an attribute of analytic-looking which is a knowledge-influenced skill. Accordingly, it can be asserted that the skilled pick-up of visual information is always knowledge-driven and that this is true whether the knowledge has been acquired over many years or for the purposes of the moment. Two other related conclusions are that everyone, whatever their level of skill, is equipped with essentially the same visual analytic apparatus and that, according to the evidence of the experiments described, this is not well structured for making accurate drawings from observation.

The Theory of Intellectual Realism

Earlier I told of my first encounter with Dr. Bill Phillips and how, he engaged me in conversation on the subject of the developmental aspects of children's drawings. Bill loved explaining things at length. So, I was in at the deep end.

Though knocked back by the flow of words in something like a foreign language that issued more and more enthusiastically from Bill's mouth (the "*English*" of an experimental psychologist), I found myself understanding enough to become progressively incredulous.

The subject of Bill's exuberance was the "*Theory of Intellectual Realism*". It had been put forward in the 1920's by Luquet[1] and given the nod of approval

1 Luquet, G. H., 1927, *Le Dessin Enfantin*, Alcan, Paris.

thirty years later by Jean Piaget,[2] the most celebrated child-psychologist of the day. It attempted to explain various well-known patterns in the development of children's drawing in terms of the catchy aphorism: "*children draw what they know, while adults draw what they see*."

Bill kept mentioning the names of scholars who had contributed to research on the subject. I was later to learn just how many hundreds of learned articles had appeared, all over the world, in psychological journals of the highest repute, written by clever and distinguished psychologists. These described elaborate and ingenious experiments designed to tease out the truth of such weighty matters as: the ages at which the significant stages in the development of children's drawings take place; whether they occurred suddenly or gradually; and whether there are differences in the patterns of change according to the category of object being drawn, etc..

And why was I incredulous? Any teacher of adult drawing will surely know the answer. How could so much work and expertise have been allowed to go into the construction of what could only be described as a castle built on sand? How had it come about that all these experts had overlooked the fact, so often demonstrated in the drawing classes of the world, that advancing years never puts a stop on the influence of knowledge on drawings. The assumption that adults draw what they see is absurd.

My response to Bill's explanations, made easy because I didn't realise the significance of my words, was something to the effect of "*what a load of rubbish.*" When Bill's surprise had abated, his rejoinder and the conversation that followed were on the following lines:

"*Can you prove what you are asserting*?"

"*Nothing could be more simple. Just come along to any adult drawing class and you will see for yourself.*"

"*I mean, can you prove it experimentally?*"

"*Of course not, I have no experience of doing experiments and no idea of how to set about proving anything by means of them*."

"*Well, I am an experienced experimenter and I would very much like to do an experiment with you with a view to proving the Theory of Intellectual Realism to be mistaken? Would you be interested?*"

2 Piaget and Inhelder,1956, *The Child's Conception of Space*, Routledge and Keegan Paul, London

After a longish pause I replied, "*All right, why not give it a try?*"

The die was cast, although, at the time, I had no intimation of what a change it was going to make to my life.

The pilot study

When confronted by the prospect of doing an experiment, two pragmatic decisions were taken. First, we would accept the "*know/see*" terminology provisionally, even though we already suspected that it might be misleading. And second, rather than demonstrate the extent to which adults draw what they "*know*", we opted to show that, at an age when the theory we were questioning asserted that they were too young to do so, children could easily be tricked into copying what they "*see*". Bill rightly saw that the concentration on children would not only ease the practicalities of experimentation but also, in the event of the results working out well, increase the chances of publication (perhaps too often, a consideration in modern science). Our hypothesis was that children, like adults, use different looking strategies for copying unfamiliar shapes than those they employ for copying familiar objects.

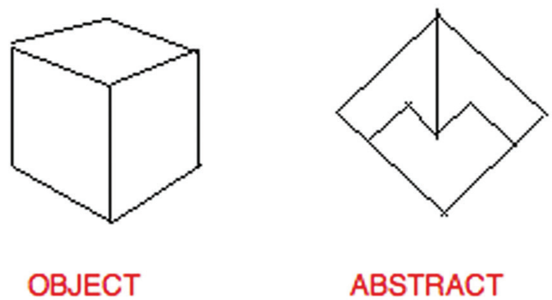

Figure 1: An object and an abstract pattern

As a preliminary, it was decided to undertake a pilot study, with the help of two of Bill's children, Ned and Fred, who at the time were conveniently seven and nine years old respectively. They were asked to copy two different line drawings as accurately as possible. One of these represented a *cube* and the other of an *abstract shape*, which had many features in common with the cube drawing, including being made up of the same number of straight lines (see *Figure 1*).

The result could not have been more spectacular. The cube copies made by

Ned and Fred were typical of children's drawings of cubes, bearing little resemblance to the model, while the abstract-shape copies were easily recognisable as the shapes from which they were derived. In the terminology of the *Theory of Intellectual Realism*, Bill's children had drawn the cube based on "*what they know*" and the abstract shape on "*what they see*".

This was the result I had predicted and which Bill had wanted. Indeed, he was very excited by it and, as soon as he could, he arranged for one of his students to do a properly controlled experimental study, using the number of children required for an acceptable statistical analysis. The results were exactly the same as those from the pilot study, the statistics came out a dream and Bill and I wrote a paper, which was accepted for publication by a very respectable journal.[3]

Through all this I had very much enjoyed learning about the experimental process and, afterwards, I was really glad that the results pleased Bill and produced the publication he had hoped for. On the negative side, as I have already explained, I could not help feeling that what we were proving was something that any teacher of drawing would know already. In short, I was more interested in the process of experimentation than the subject matter we were addressing.

At the core of this interest was a growing awareness of the potential of the experimental approach to answer questions of much greater importance to me. Ones that had been swilling around in my head ever since my days as an evening-class figure-drawing teacher. For this reason I was delighted when the modest success of my first venture into experimentation led to an opportunity of doing research into a significant number of these issues. I owed this to Bill, who not only encouraged me, but also joined me in making a grant application to the Social Science Research Council to study aspects of graphic-skills. It was successful and I was given a post as a Senior Research Fellow in the Department of Psychology.

The next step

Although the grant proposal described matters in a more elaborate and academic sounding way, the question that interested me can be more simply expressed, namely, "*why do people make errors when they make drawings of objects from observation?*". For the time being , my focus was on what the experiments would show about *the skilled use of visually derived information in terms of eye, brain and hand coordination*. However, I also had a longer term interest. This re-

3 Phillips, W. A., Hobbs, S. B. and Pratt, F. R., 1978, "*Intellectual Realism in Children's' drawings of Cubes*". Cognition, Vol.. 6, pages 15-33.

lated to ideas about creativity that I had been mulling over. It was the possibility of developing these that more than anything else, explained the high level of my enthusiasm for the project.

Those of my artist friends whom I told about my entry into research were dismissive of the whole enterprise. They could see no relation between slavish accuracy and their idea either of "*creativity*" or of "*art*". For my part, while never being quite able to banish the niggling doubt that they might turn out to be right, I hoped otherwise. My tentative optimism was based on my evening-class experience, which showed that efforts to help people with their aspirations for accuracy could lead, by way of the necessarily greater awareness of abstract qualities, to highly personal and creative productions. However, it was to be a long time before the research results would give the kind of support that I was seeking. Three years of experimentation were to pass by before light began to appear at the end of the tunnel.

Although my big toe had already been dangled in the waters of scientific research, it was now a matter of jumping in at the deep end. Being only too aware of my inexperience, I was full of uncertainties and worries. The most basic of these was whether, under experimental conditions, adults would come up with the clean-cut results necessary for providing statistical significance. For example, if they were given the task of copying line drawings of familiar and unfamiliar objects, would the differences between the two categories of copy be sufficiently evident?

There was no need to have worried.

The main experiments

Our first decision was that, if we were going to investigate the causes of copying errors, it would be necessary to compare people who could be expected to differ in their performance. Accordingly, for the first set of three experiments, we decided to study three groups. These were *art students* (representing skilled adults), *psychology students* with no artistic pretensions (representing unskilled adults) and *eight year old children* (representing young children at the stage of making so-called intellectually realistic drawings).

A preliminary anxiety derived from the abundant evidence that knowledge can work in two directions. Thus, different traditional artistic practices demonstrate that the accuracy of drawings from observation can be improved, both by bypassing knowledge (for example, by looking at familiar objects in unfamiliar ways) and by making use of it (for example, by using knowledge about anatomy or perspective). Would these long established findings confuse the results of the experiments? The only thing was to get on with it and see.

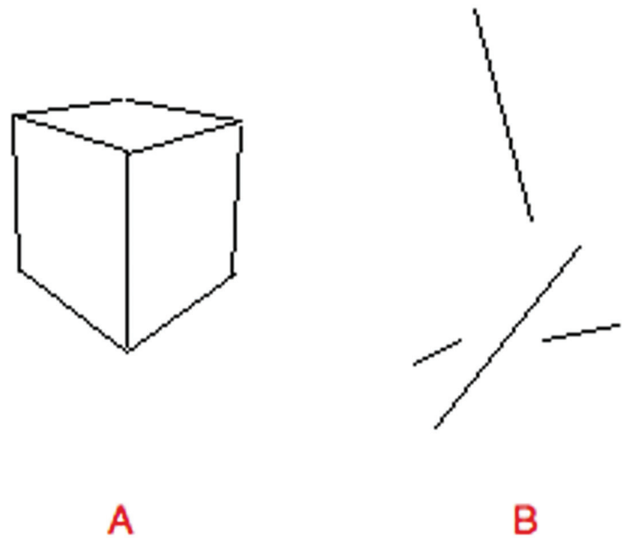

Figure 2 : examples of models used

The same set of tasks was given to each of the three groups. All involved making copies of a number of lines drawn on pieces of A4 paper (henceforward referred to as the "*models*"). There were two categories of model. In one, the lines took the form of a *familiar object*, such as the cube in *Figure 2A* , while, in the other, they took the form either of an *unfamiliar shape* or of *groups of 2, 4 or 8 straight lines* as in *Figure 2B.* In these latter, the orientations, lengths and positions on the page of the lines were chosen by a random procedure and were not permitted to touch either each other or the edge of the paper. They were referred to as the "*random-straight-line*" or "*RSL"* models.

The experimental set-up is illustrated in *Figure 3*. The *RSL* models were attached, one at a time, to a drawing board, which was placed on an easel situated at a fixed distance (a couple of paces) in front of the person doing the experiment (hence-forward called "*the subject*"). The task was always to copy the model on another piece of paper which was blank, larger and squarer than that on which the model was drawn (the difference in dimensions was to deter the use of the edges of the paper as referents). The subjects were seated on a high stool (which acted as a useful constraint on the viewing position). To make the task requirement quite clear, they were instructed that their aim should be to make copies such that, when finished, they would fit over the models as if they were tracings. Since the results might be spoilt if the subjects felt too daunted, they were assured that, unless they were very exceptional people indeed, they would not succeed in this objective. "*Just try to do the best you can*", they were urged.

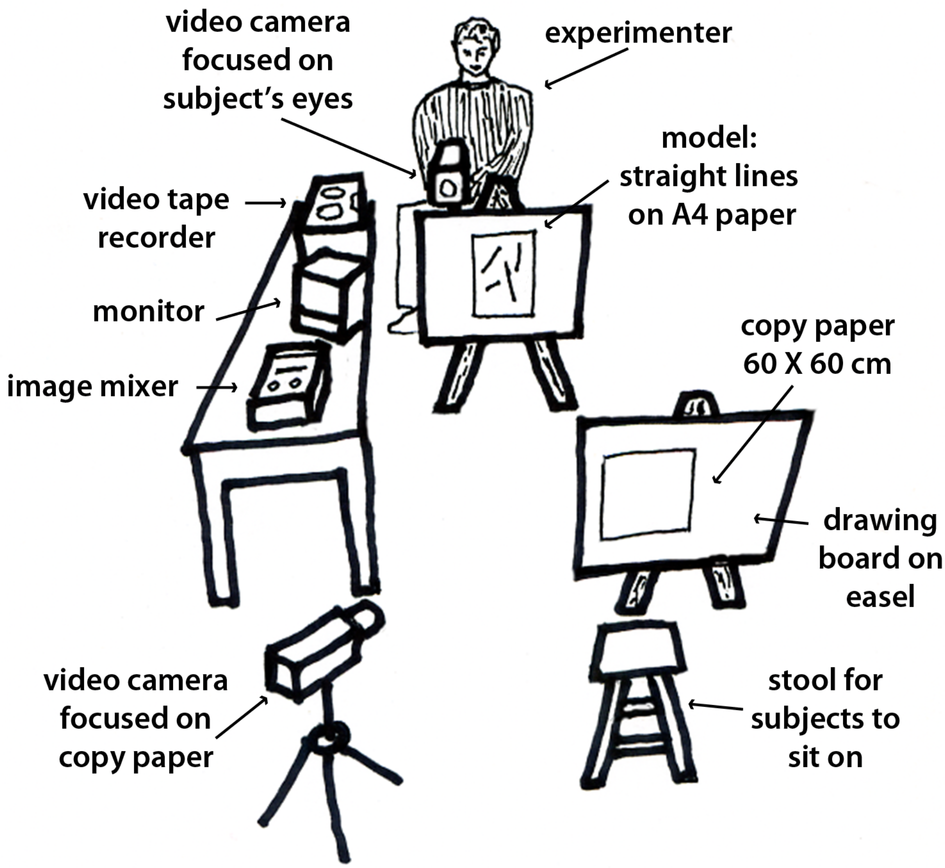

Figure 3: the experimental set-up

Copies were made under two kinds of drawing conditions. In one of these the subjects were free to behave *normally*, looking back and forth between model and copy, as much as they liked. In the other, they had to rely on *memory*. There were two memory conditions. Thus subjects were allowed either *two seconds* or *fifteen seconds* for analysing the model, before it was hidden from their view and they were permitted to start their copy.

In addition, two video cameras were installed. One of these was directed towards the eyes of the subject, such that the video-record it produced indicated whether they were looking at the copy or the model. The other was directed at the subject's drawing hand. The images from the two cameras were displayed next to one another on a split-screen, in such a way that it was easy to relate line-production to looking-behaviour.

The main results

The main results were surprising for their simplicity and clarity. Fortunately, when copying the *familiar objects*, whether normally or from memory, the art students performed the best, the psychology students the next best and the eight year olds (with some interesting exceptions) the worst. If this had not been the case, the classification into skilled and unskilled adults would have been shown to be meaningless.

In striking contrast, when copying abstract patterns or *RSL models*, there was no significant difference between the two groups of adults for any of the copying conditions and precious few between the adults and the children.

Error sizes

Before the experiments, we had no idea concerning the likely size of errors. It was, therefore, very revealing to discover that, according to the standard of absolute accuracy that we were using, everybody performed rather badly. This result was of fundamental interest for it indicated that the art students' talent for drawing did not depend on a special ability to make visual measurements of the dimensions of the model. Since their superiority was shown only when copying familiar objects, it also implied that the basis of their skill resided in superior knowledge of some sort.

Meanwhile, looking at matters from the point of view of an art teacher, I could not help noticing that these findings placed a large question-mark under teaching methods used for helping people to draw accurately by encouraging analysis in terms of unfamiliar aspects of objects, particularly those that depend on calling attention to so-called *negative shapes*. Although these have proved their value too often in too many drawing classes to reject them, the poor performance in copying the unfamiliar models supports the view that some of the claims made for them are excessive. Clearly, the strategy of looking at objects in unfamiliar ways is not the complete answer.[4]

So, what were the error sizes? To find out, we used six measures of accuracy. Two of these depended on differences in terms of absolute measurements. Thus, if the copy were to placed on top of the model, "*like a tracing*", the discrepancies between the two in respect of both angle and line-length would constitute absolute measurement errors. The other four measures related to relativities. Thus, if a copy had been exactly twice as big as a model, the absolute measure relating to line length would have shown an error of 100%, while the relative measure would have shown one of 0%. Similarly, if all the lines in the copy were drawn squint by five degrees, then its absolute error would be 5 degrees and the relative error would be zero degrees.

Analysis of the absolute measures gave yet more support for the already abundant evidence that visual analysis relates to relativities and not to absolutes. Thus, the frequent occurrence of huge line-length errors (often over 50%) merely confirmed that which was already well known.

The relative measures were more interesting. Though they were in general a great deal smaller than the absolute measures, they still averaged in the region of 10% for line length, 10% for position on the page, 10% for a measure that combined length and position and 5° for angle. These figures are bad enough but averages can hide a great deal. In this case, they obscure the true gravity of the situation, which was revealed by the wide spread of error-sizes. Thus, while, on the one hand, many of the inaccuracies were very small, even approaching zero, on the other, errors of the order of 20% for length and 10° for angle were far from rare and, indeed, on a surprisingly large number of occasions these figures were far exceeded.

A looking-strategy explanation

A plausible explanation of the variability in accuracy just described is that some kinds of inter-line relativities provide better opportunities for error-reducing strategies automatically adopted, even by unskilled adults. *Figure 4A* provides an example. It shows two lines, which are roughly equal in length, not far from parallel and in close proximity. As a result, rather than trying to judge the line-lengths as a whole, a more natural strategy would be to make estimates, first of the amount by which one of the lines is longer and, second, to the distances between their endpoints. Approaching matters this way might well produce an

4 More on this subject in *Vol.2, Chapter 4*

almost perfect copy. The reason why is not difficult to work out. Thus, in the case of the relative-length measure, the subject's poor capacity for visual measurement is being used, not to estimate separately and compare the whole lengths of the two lines, but only to judge the difference between them. Since this so small, even a comparatively large over-estimate or under-estimate could still leave an excellent copy.

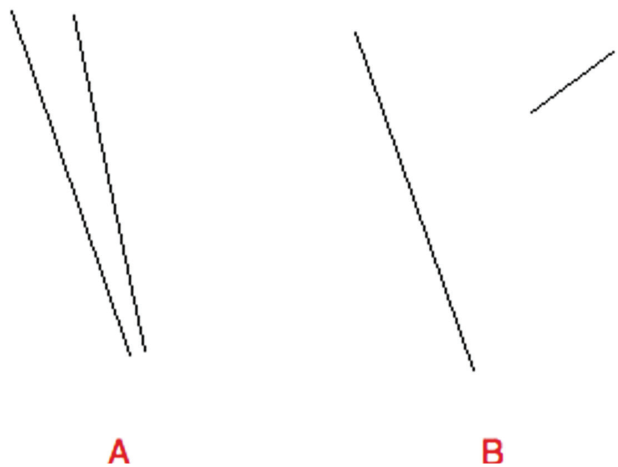

Figure 4: two pairs of lines that are (a) easier and (b) more difficult to copy accurately

A similar logic can be applied to the orientation judgement. Thus, as an alternative to judging the angle between the lines directly, it is possible to concentrate on the lengths of the distances between the two pairs of end-points. The resulting angular relation might be almost spot on, for it would take an unusually large misjudgment of either or both these distances to create a noticeable error.

In contrast, using the same strategy for making copies of a models where the lines are not only far apart in space but also very different in length and orientation (such as *Figure 4B*), would typically produce a very poor results indeed.

The deliberate-mistakes experiment

In view of the ambiguity of the situation, it was decided to investigate further by means of another experiment. For this we prepared a set of copies of four-line RSL models, in which there were a number of deliberate mistakes. The subjects were shown both model and copy and their task was to correct all of the mistakes they could detect. They were told neither how many of them there were nor how big they might be. In fact there were either one or three mistakes in every copy and the size of errors was always 10% for line-lengths and 5 degree for angles (that is to say, the same as the average errors found in the previous experiments).

The findings from this experiment were extremely interesting. First, despite the fact that the subjects were given as much time as they wanted and not withstanding their very evident commitment to the task, *about one third of the errors went unnoticed*. This result alone makes it abundantly clear that people aspiring to make accurate copies are up against some very fundamental visual-measurement problems. A second, perhaps even more surprising result concerned the number of corrections made which actually turned out to be *worse than the mistake they were supposed to be correcting*. These were sufficiently frequent that, on average, the corrected copies were no more accurate than the originals.

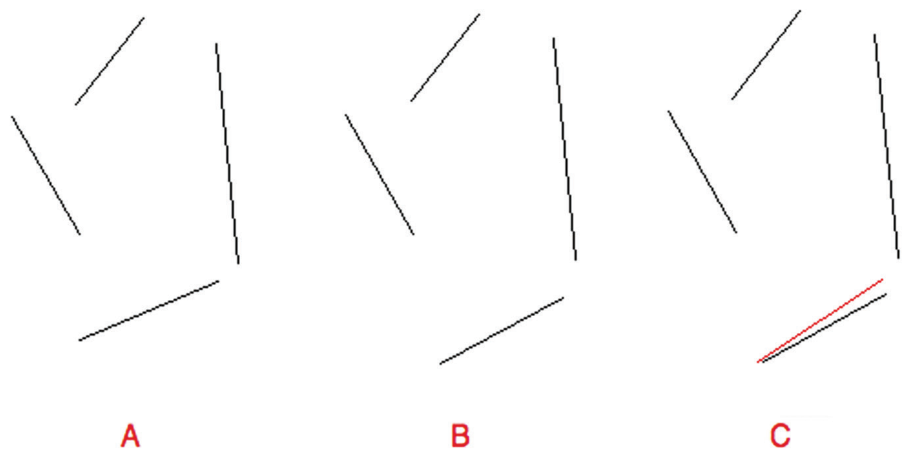

Figure 5: compounding an error

An example of what happened is illustrated in *Figure 5*. In this *A* is the model, *B* is the copy, containing one deliberate mistake (the lowest of the lines) and *C* the correction (indicated in red) which shows an error of 15°, that is to say three times worse than the deliberate error of 5 degrees. A plausible explanation for this astonishing deterioration between the deliberately mistake and its correction rests on three assumptions that derived from my experience as a teacher and which are given force by the lack of plausible alternatives. The first of these is that the subject noticed only the most eye-catching aspect of the deliberate mistake, namely the greater distance between the right-hand end of the line needing correction and the bottom end of the near vertical line in close proximity to it. The second is that, with his attention elsewhere, he failed to notice either to the displacement of the other end of the erroneous line or to the angular error. He therefore anchors it to the end of the line he has perceived as the deliberate error. The third assumption is that, having made his correction, he did not look back at what he had done to check it out. Had he done so he would have surely that something was very wrong. It is worth noting that this third assumption got support from the video-tape recording of the normal copying experiment, which suggested that looking back was a rare occurrence. People's eyes seemed always to be rushing on to the next line, even before the pen had completed the process of drawing its predecessor.

Not noticing the displacement of the left-hand end of the line can be regarded as an example of the general difficulty of making judgements in unfavourable contexts. Failing to give adequate consideration to the angle of the corrected line fits well with other evidence suggesting that many people tend to concentrate on relations between endpoints of lines rather than on the properties of the lines themselves.[5] *Not checking back*, though at first sight astonishing in the context of an error-correction task, provides an example of a phenomenon which is common, not only in the drawing class but in life in general. It would seem that no matter how great the evidence of their fallibility, human beings have a tendency to opt for *muddling through* regardless. This can be a good strategy in a great many everyday life situations, but will not favour the development of skills such as those required for making accurate copies. *The process of learning of skills of any kind depends heavily of the use of feedback*.

If the above explanations are correct, then it becomes evident that the difficulty of achieving accuracy is due not only in an *inability to make accurate visual measurements* but also to the *negative influence of habits of looking*. Thus, a general method of improving performance is to substitute new effective habits for old ineffectual ones. For example, it would clearly help if special effort could be made to check all lines immediately after their production. Unfortunately, making changes of this kind, however simple they may seem intellectually, is easier said than done for, as everyone knows, *habits can be very deeply ingrained*.

5 As just indicated, in some circumstances, this can be a good strategy.

Looking strategies

The video-tape record of *looking behaviour* provided a lot of promising information. Thus, for example, it showed that when the skilled adults copied the object models (which they did more accurately) they engaged in about twice as much looking activity as the unskilled adults. In striking contrast, when they copied the RSL patterns (which they did *not* do any more accurately), they did the same amount of it. Thus, the experiment indicated *a three way interdependence between looking activity, familiarity with the model* and *copying accuracy*.

The record also provided information about looking-times. The majority of looks at the model could best be described as "*glances*", since they lasted for less than one second and many for less than a half a second. However, there were also a significant number of longer looks with a duration of two or more seconds. These last were particularly in evidence when the art students were copying the object models. In contrast, they were hardly used all by the psychology students and seldom by the art students when copying the RSL models. Thus, once more, the experimental findings indicated a *correlation between knowing something about what you are looking at and looking behaviou*r.

The shorter looks take on more significance in the light of research findings about how eyes operate. There will be much to say on this subject later, but, for the moment, it is only relevant to know that eyes never keep still. Rather, they are moving all the time in one of three different ways. Thus, as well as a continuous tremor, they make rapid, jumpy movements ("*saccades*") and slower gliding movements ("*ocular drift*"). The time taken for the combination of a saccade and an ocular drift is a little more than one third of a second.[6] What this means is that looks of less than half a second will contain only one information-capturing glance, while looks of between half a second and one second will contain two.

The role of memory in looking strategies

A number of interesting findings came from the drawing-from-memory task. Thus, when the skilled adults were confronted with a familiar-object model, containing nine lines (for example, in the cube drawing in *Figure 2A*), they could pick up enough information in the time allowed to enable the production of impressively accurate copies. In contrast, when faced with the eight-line RSL mod-

6 Campbell, F. W. and Wurtz, R.M., 1978, Saccadic omission: why we do not see greying out during saccadic eye movement. Vision Research: Vol. 18 pp. 1297-1303

els, they were all at sea. The clear message from this is that *knowledge can help the efficiency of information pick-up*.

The use of memory is taken so much for granted that it is easy to overlook, not only the amount of work the brain has to do in order to structure it but also the time it takes to learn the skill of being able to do so. In this context, one of the findings relating to the young children was particularly interesting. In general their performance for the memory conditions was considerably worse than that the adults. Indeed, they were completely unable to cope the task they were set in all but one of the RSL model memory conditions. The exception was when only two lines had to be remembered. Even when confronted with this seemingly ultra simple situation, they were helplessly lost when only allowed to look at it for two seconds. However, if they had fifteen seconds of looking time, *their copying from memory performance came up to adult levels*. Clearly the eight year old children needed extra time to structure the information required by the brain for organising the output of accurate copies.[7]

This *need for more pick up time during the earlier stages of skill development is highly significant* since, as we shall see next, it generalises to the preliminary stages of all skill acquisition (and, maybe, to advanced stages too).

Short-term-visual-memory

Both the importance of the process of structuring memories and the connection between knowledge, longer looks and better performance, led to the computer-controlled experiment to be described below. Another factor in its genesis was my knowledge of the research of my colleague Bill Phillips.

When I first met Bill, his research centred on *short-term visual memory* (*STVM*). He designed many experiments to find out more about its properties and, in particular, its capacity for perseverance. What he discovered is that each brain-guided act (which might be anything, including line-production or the use of the imagination) obscures or "*masks*" the information gathered in preparing for the previous one. He described his results in terms of the "*fragility*" of short-term visual memory.[8]

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7 Compare: Vurpillot, E, 1976, The Visual World of the Child, Allen and Unwin, London, who also found evidence of slow memory structuring times in young children.

8 W. A. Phillips, 1984, Short Term Visual Memory, Transactions of the Royal Society. In this and other papers Bill conclusively demonstrated *the extreme fragility of short-term visual memory*.

The computer-controlled experiment

The mindset produced by Bill's findings was key to our thought processes when we reflected upon the revelations of the video-tape record of looking behaviour. Amongst the various ideas that emerged was a hypothesis that we decided to test. The argument that gave rise to this was as follows. If both *acts of comparison* and the *organisation of actions* disrupt aspects of visual-memory, then the process of copying must require a more robust and longer-term memory-store to guide any coordinated and efficient looking strategy. We already knew from the superior performance of the skilled adults for drawing familiar objects from memory that this function could be performed by *long-term memory*. However, what about unfamiliar objects or the complex curves which describe the ever changing shapes of familiar ones?

As suggested above, efficient visual analysis of these might require the creation of a purpose-specific memory store, structured with the help of longer looks, such as those recorded on the videotape. Thus, our hypothesis was that the function of the longer looks is to create a memory store containing knowledge of what to look for subsequently. The advantage would be reaped in terms of the pick-up efficiency of the inter-saccadic glances. Given that time taken for each of these is fixed, it follows that the learning process must enable more information to be picked up in the same time frame. Such a feat could only be achieved if appropriate, purpose specific memory structures had been created.[9]

The computer-controlled experiment in question was used to test these ideas. A sequence of different two-line RSL models was displayed on a computer screen. At a given time after a model appeared, one of the two lines disappeared and the subjects were asked to copy the one that remained. The time before the disappearance was either one-third of a second or five seconds. When the subjects had completed drawing the visible line, they pressed a button which caused the second line to reappear for either one-third of a second (allowing time for one glance) or two-thirds of a second (allowing time for two glances). The question was whether the information collected in the five-second preliminary look would lead to better pick-up of information by the final glance or glances.

The answer was a clear 'yes'. Without the preliminary five-second look, when doing their best to copy the second line, the subjects were all-over-the-place. In contrast, with the extra looking time, they performed almost as well as if the image was there in front of their eyes.

9 In the previous chapter, referred to as "*working-memory*"

This result gave strong support to the hypothesis that temporary knowledge, acquired as a result of appropriately organised looking behaviour, could play a vital role in achieving copying accuracy.

De Groot and the Grand Masters

One way of clarifying the importance of these results is to compare them with those produced by another experiment from a completely different sphere, namely that of chess. Just as the experiments detailed in this chapter compare skilled and unskilled draughtsmen, the Dutch researcher de Groot looks at differences between skilled and unskilled chess players. For his skilled subjects he went straight to the top, obtaining the cooperation of accredited Grand Masters.[10]

In the first part of the experiment, the Grand Masters were shown a game of chess, which had advanced past the opening stages into what is known as the middle game (i.e. When it is at its most complex). After allowing a brief looking-time, the chess pieces were removed from sight. The task required was to reconstruct the game from memory. Incredibly, all the Grand Masters could do it.

The next step was to give the same task to unskilled chess players. Not surprisingly, these ordinary mortals were completely flummoxed. There could be no doubt that, in the domain of their preeminence, Grand Masters do have special *knowledge-storage* capacities.

But this was only half the experiment. De Groot now asked the same two groups of people to repeat exactly the same task, only this time the chess pieces were placed at random on the board. The result was spectacular: As a consequence of this one change, the Grand Masters were just as much at sea as the ordinary mortals. The conclusion to be drawn is both simple and clear: The Grand Master's feats of rapid information pick-up depended on the existence of previously structured knowledge.

The similarity between de Groot's findings and those described earlier in this chapter is striking. In combination they provide strong support for the assertion that the skilled pick-up of visual information is always knowledge-driven and that this is true whether the knowledge has been acquired over many years (long term memory) or for the purposes of the moment (working memory).

10 de Groot, 1965, "*Thought and Choice in Chess*", Mouton, The Hague

Implications

Although I found my initiation into the world of controlled experiment to be mind expanding and although I felt that important progress was being made, my strongest reaction related to a growing awareness of the complexity of the subject I was studying. It became obvious to me that I needed a better understanding how eyes and brains work.

My attention now turned to the question of how to tackle this seemingly daunting subject. Naturally, my previously existing ideas on drawing skills had an influence on the approach I chose. For example, I already knew that it is possible to "draw what you know" with hardly any looking at all. In other words, if ever knowledge exists in memory, task-implementing skills can be activated by means of the least of cues necessary for accessing it. Thus an early question I had in my mind was "what is the minimum information required to enable access to that knowledge via recognition?" My video records showed that, whatever the answer, it would have to be picked up in less than half a second.

This contrasted with the multiple looks, often lasting a number of seconds, required by the analytic looking systems. Clearly, there must be a significant difference between the cues required to trigger recognition and those necessary for supporting analysis.

Similarly, my interest in learning to see in new ways had important consequences. It meant that my attention was would have to be concentrated on the entire drawing process, including:

- *The primary source of input.*
- *The visual systems in eye and brain that enable recognition.*
- *The visual systems in eye and brain, collectively known as the analytic-looking system.*
- *The output instructions that enable the coordinated actions which produce an emerging drawing.*
- *The emerging drawing.*

And, from there, back to the start of the cycle, but now furnished with an additional primary source of input.

Clearly, there was a lot to find out and, to make progress, it would be important keep all parts of this cycle firmly in mind.