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ACHIEVING PLEASURE FROM PURPOSE

The methods of Kenneth Grange, product designer

Nigel Cross

Abstract

This paper is based on a case study of the working methods of a highly successful product designer, Kenneth Grange. Relevant aspects of his personal background are introduced. Three of his well-known projects are selected for analysis: a camera for Kodak, a sewing machine for Maruzen, and the British Rail High Speed Train. His designs are characterised by a concern with designing for purpose, so as to achieve pleasure for the user. General lessons are drawn from the examples, and comparisons are made with other studies of highly successful designers. Similarities with these others include a tendency to develop a systems view of the problem; defining or framing the problem to be solved in a fresh, challenging way; and developing details from basic principles of function, engineering and manufacture.

Studying Expert Designers

This case study is a contribution to the slowly growing number of studies that have appeared in recent years of highly creative, innovative and successful designers, such as those by Roy (1993), Lawson (1994), Cross and Clayburn Cross (1996). The motivations for such studies include improving our understanding of the psychology of creative behaviour, identifying features of successful design performance that might be possible to develop through educational processes, and developing models of the innovative design process.

Kenneth Grange is a well-known and highly successful designer of a great variety of products that range in scale from ball-point pens and disposable razors to train seats and railway engines. His career has spanned over more than forty years, and many of his designs became (and remain) familiar items in the household or on the street - or on the railtrack. These designs include the first UK parking meters for Venner, food mixers for Kenwood, razors for Wilkinson Sword, cameras for Kodak, typewriters for Imperial, clothes irons for Morphy Richards, cigarette lighters for Ronson, washing machines for Bendix, pens for Parker, and the British Rail high-speed train. He is one of the Royal Society of Arts' élite corps of 'Royal Designers for Industry', and his designs have won ten Design Council Awards and the Duke of Edinburgh's prize for elegant Design. His career began with his first independent commissions in the nineteen-fifties, and in 1972 he was a founding-partner in what was to become the world-renowned interdisciplinary design consultancy, Pentagram.

This study is based on informal conversations with Kenneth Grange and a more formal, taped interview specifically for this study, and on his own previous published account of his work (Grange, 1983). The main purpose in preparing this study is to seek insight into the design processes of someone who has a long history of being a successful, innovative designer.

Background

Kenneth Grange's highly successful career appears to have started and developed initially by a series of accidents. Born in London in 1929, the son of a policeman, the fourteen-year-old Kenneth 'put his hand up' at school to apply for a scholarship to Art School. When he won the scholarship, to Willesden School of Arts and Crafts, his mother was pleased but his father feared that the boy would only end up in what he, as a policeman, knew as the seedy, bohemian world of artists. This worry was there despite his father's own interests in the arts, and skill as a draughtsman in copying classical paintings, and the flourishing artistic strain of musicians in his father's family.

After four years at Art School, where 'all I really learned was draughtsmanship', and a short job as a scene painter with the BBC's fledgling television department, the Principal of the Art School recommended Kenneth to 'go and see a woman who had been a student with him and who was working in the Institute of Town Planning'. This contact in turn recommended him to some architect friends of hers, who turned out to be the firm of Arcon, a leading progressive architectural firm of that era. Kenneth recalls that 'I had never heard of architecture, I hadn't the slightest idea of what this meant, but they gave me a job in what they called their technical publications department', making presentation drawings for clients.

Kenneth was then soon after, at age nineteen, subject to two years of conscription into the Army, where his 'little portfolio' of drawings got him allocated as an illustrator producing drawings for instruction manuals. This work involved taking apart, usually by personal trial and error, various artillery mechanisms, and then making drawings to illustrate the parts and their assembly. This self-instruction in the assembly and re-assembly of military machines became Kenneth's introduction to engineering, and the beginning of his fascination with the way things work, with the necessities of practicality and function that became underlying principles of his approach to design.

After leaving the Army, Kenneth returned to his architect colleagues for work. One of the Arcon partners, Jack Howe, recommended him to another architect, Bronek Katz, for whom he worked for a year or two, and then for another couple of years with Gordon Bowyer. Then he began to work again with Jack Howe, who also encouraged Kenneth to undertake some independent work of his own. These

private jobs were mostly 'week-ends painting a mural or whatever. But a little job I somehow picked up . . . was doing an exhibition for the then Atomic Energy Authority.' This little job was so successful that the client called him again some months later, to say 'We've taken space at an exhibition in Geneva, and would you like to design the exhibition stand for us?' But the new job turned out to be too large for Kenneth to be able to cope with on his own, so he offered to Jack Howe to bring it into the office, and was 'shattered' when Howe said it would be better for Kenneth to leave and start up on his own. 'I was absolutely thunderstruck, but within a month I'd got three people working for me full-time, and we were working in my flat, we'd taken over the living-room as well as the little office-workshop I'd got, and with every week the job increased. . . It turned into a big, big job.' And so the Kenneth Grange design consultancy was accidentally up and running.

Product Innovations

A significant feature of much of Kenneth Grange's design work is that it is not based on just the styling or re-styling of a product. His designs often arise from a fundamental reassessment of the purpose, function and use of the product. However, this radical, innovative ability is not necessarily the reason why clients invite him to take on a new job. He says, 'You are invariably brought in by somebody who has got a very elementary commercial motive in changing the perception of the product. It's extremely unusual for someone to be brought in to approach it from this usability, this function theme.' But he feels the need for a 'secure foundation' when starting a new project, and that foundation is the product functionality. 'I am never daunted by the blank paper because I know I can at least fill in my time by trying to sort out just the functionality, just the handling of it, and by-and-large out of that comes a direction, and then it's a question of tuning. . . I think it's back to what your temperament is, your personality. I think with my background and my own knowledge about my weaknesses I am bound to need to have a secure foundation on which I stand when I am arguing about something, and I am not very comfortable when I find myself required to be the prima donna.'

His practical attitude towards product functionality also extends into his normal, everyday life. 'As I get older I get less and less tolerant of things that don't work easily, and so I think I go around looking for trouble!' As an example, he recounts a recent experience in a restaurant, specialising in serving steamed mussels: 'The waiter comes along and dumps on the table a big stainless steel bowl (of mussels) with a lid, and this is hot. My companion's lid had handles on it, and mine didn't have handles on it. That made me furious, and I alone in that restaurant - probably they have never had anybody else complain about it - but not Grange - he shouts and hollers and tells the waiter and calls for the manager. I can't resist it, because I find that so much like a real affront!'

Example 1: Kodak Brownie Vecta Camera

Kenneth Grange's long-lasting working relationship with Kodak began as another 'accident' arising from one of his early exhibition designs, in association with Jack Howe - a pavilion for Kodak at the World Fair in Brussels, 1958. 'One evening inside the building, I remarked to a kindly man nearby that the display of the cameras would be greatly improved if the designs of the products themselves were better. He replied that if that's what I thought, then how much would I charge to design a camera for them? I forget how much I said, but it was probably less than £150. That was the end of the conversation, and it had gone from my mind when three days later a certain Dr Pitt called me in London. He said laconically that he understood from the Kodak sales director I had met in Brussels that I was going to design a camera for them!' The result was a commission to design a new camera - the Kodak 44A, which was Kodak's first serious attempt to produce a camera that was profitable in its own right, rather than simply being a vehicle for assisting the sale of Kodak film. The neat and practical 44A succeeded in establishing Kodak's camera division as a profitable enterprise, and Kenneth was retained, over a period lasting more than twenty years, to design many other products, including the Instamatic series of cameras.

The Kodak Brownie Vecta camera (Figure 1), designed a few years after the 44A, provides a good example of Kenneth Grange's ability to bring a fresh viewpoint (literally in this case) to a familiar product, by starting from an understanding of what the user of the product wants to achieve. The brief was simply to design a plastic moulded variant of a standard camera. The design process, however, was a significant re-thinking of the simple snapshot camera, based on how, and for what, it is used. The result was the conventional camera body turned through ninety degrees, so that its normal orientation gave a vertical 'portrait' rather than a horizontal 'landscape' framing of the picture.



Figure 1 *The Kodak Brownie Vecta camera*

Kenneth had been building up his relationship with Kodak, designing a variety of in-house, non-consumer products such as film processing machines, as well as company exhibitions, packaging, and products such as cameras and projectors. As a result, he was able to visit company premises and factories, such as the huge film processing laboratories. 'I realised, just going around, that very commonly you would see most pictures were of people, and many of those pictures were were of one person or at the most two. So you have got this contradiction, you have a landscape format for a portrait, and I knew that if you turned it around the image on the film would be better, bigger, therefore the chemistry would be better, the print would be better, etc. [Most prints then were contact prints direct from the negative, not enlarged prints.] So that was the motive for the Vecta, and I set up the design for the film to wind vertically and that meant quite a lot of juggling with the shapes and contours so you could hold the thing.' (Figure 2) Referring to his restaurant experience, he concludes, 'So it's not unlike the missing handles on the mussels-pan; you see something and you think it's a contradiction!'

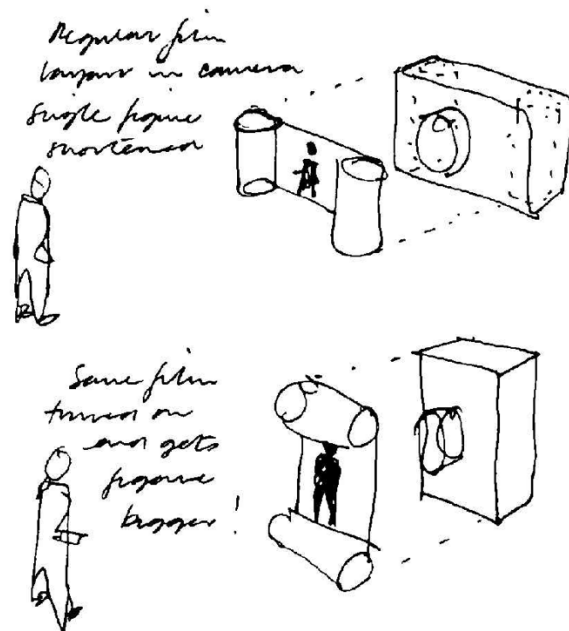


Figure 2 Kenneth Grange's perception of the reorientation of a snapshot camera so as to obtain a better image

This example of the Vecta camera illustrates Kenneth Grange's ability to take a fresh look at a standard problem. It is as though his ability is primarily perceptual - not something that he has to work and worry at until he gets an idea, and not something that emerges in the process of designing so much as the process of initial problem formulation. He agrees with this interpretation: 'You do have to ferret around, which is like an intellectual bit of it, to see, to find that which is then suddenly obvious to you, and I think that has

happened very often. Sometimes you almost have to fabricate the problem.' He reinterprets, or brings a fresh perception to the design problem so as to establish a new concept, and the rest is working this through; the perceptive insight gives 'a direction, and then it's a question of tuning.'

Example 2: Frister & Rossman Sewing Machine

In the mid-1960s Kenneth Grange was asked by the Maruzen company of Osaka, Japan, to design a new sewing machine for them. Maruzen produced high-quality, well-engineered machines (sold in Europe under the name Frister & Rossman), but were looking for new designs for their European market. Kenneth's resulting design incorporated the standard Maruzen machinery, but repackaged it in novel ways that made it easier to use and gave the overall machine a new and distinctive form and style (Figure 3).



Figure 3 *The Frister & Rossman sewing machine for Maruzen*

The origins of the new design features lay in Kenneth's functional, practical approach, and on his personal experience. His starting point was his own use of a sewing machine: 'I chose to use it, actually making things with a sewing machine, so I did fairly quickly come to understand just fundamental strengths and weaknesses'. He found another 'contradiction', in the sewing machine mechanism being located centrally on its base, whereas the user needs more surface space on their side of the needle than behind it. 'In front of the needle, the longer the table on which you can actually assemble and lay and just get the tension of the fabrics right, the better. Once the work is behind the needle you can do nothing about it, it's sewn, therefore you don't need any space for the fabric.' Kenneth therefore simply moved the sewing machine mechanism rearwards on its base, creating an off-centre layout with more base-table space in front of the needle than behind it. To him, this appeared a virtually self-evident improvement to make: 'This is such a straightforward thing

to do, but the reason it had not been done before was because the sewing machine had been designed as a very straightforward, basic piece of engineering which needed stability. Therefore the mechanism was from the very beginning put centrally upon the base and nobody had thought about challenging the space beyond and the space in front of the needle.' Once this challenge had been met, and the benefit of an off-centre layout perceived, then 'the rest of the shape follows, the rest of the shape just absolutely falls into place from that'.

Another radical change in this particular sewing machine design was also a result of a simple, fundamental assessment of how the machine is used. Kenneth gave the base of the machine radiused lower edges, which look like a mere 'styling' feature, but in fact also arose from function. 'There was something that they told me, which is that a frequent problem with sewing machines, particularly when you are sewing a new fabric, is that a lot of lint comes off the fabric, loose fibres and so on. This gets down into the bobbin and at worst stops the machine, at best will get itself sewn back into the thing, so you haven't got an absolutely clean stitch, which affects the tension, the thread, etc. And they said, this is a problem, and their way of dealing with it was to make sure you could open the front and get the bobbin out.' This was achieved by the user tilting the machine backwards, into a precarious, unstable position that only allowed restricted access to the shuttle mechanism.

To Kenneth Grange, this was simply inadequate. 'I thought, that doesn't seem to me to be very clever, why don't we make sure we can open the thing and really get at it? So I tilted the thing sideways, I rolled the whole thing back so it stood up and was very firm, and you could get the whole of the guts apart and get at the lint and so on, and that in itself generated a shape because then the edge of the machine naturally had a roll to it.' The rolled edge made it easier for the user to tilt the machine, it rested stable and secure on its handwheel, and the underside was accessible for cleaning and oiling the lower mechanisms. A radiused top front edge was also provided to the base plate, to allow the fabric to slide over it more easily, and various other features were added, such as small drawers for holding accessories (Figure 4).

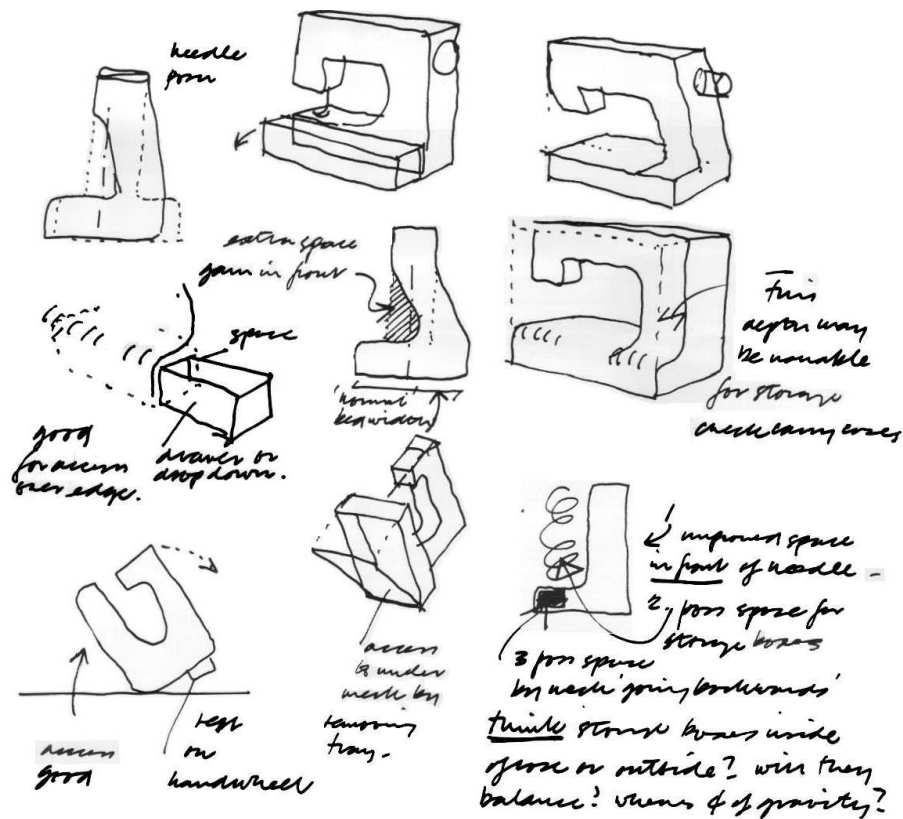


Figure 4 Kenneth Grange's sketches summarising some of the principles underlying his design of the sewing machine

The sewing machine again illustrates how Kenneth Grange approaches design from a functional viewpoint. The innovative 'style' and features of the new machine were generated from considering and responding to the normal patterns of its use. He says, 'I think it's a question of what your attitude is towards anything, any working thing. My attitude is to want it to be a pleasure to operate.' Another aspect of this approach is that he considers the whole pattern of use, as exemplified by considering the requirements of periodically cleaning the machine, and by considering how the user prepares and introduces the fabric into the stitching mechanism, thus requiring more make-up space in front of the needle than behind it. It is a fundamental part of his interest in how things work: 'Those are the things that intrigue me, recognising that there is a difference between what happens after a particular process and what happens before it, and so on, and preparing yourself for those two stages.'

It was perhaps that success, and others like it, stemming from going beyond the original brief, that helped form his sceptical attitude towards developing and following a tight initial specification. The designer's job, he says, is 'to produce the unexpected'. And that does not happen by trying to 'get the brief right, go through the process in an orderly fashion, check that you have done what you have been told to do.' Instead, 'It's the little bits of inspiration, the little sort of byways and the unlikely analogies and things that eventually

produce what you recognise as being the right thing to do.' He suggests that 'No brief of itself ever produced an unexpected market leader. Success lies in finding the chinks in the specifications and reaching through to the concealed plums.'

Example 3: British Rail High Speed Train

Going well beyond the requirements of the original brief was also a major feature of one of Kenneth Grange's most prestigious designs - the front bodywork of the High Speed Train introduced into passenger service by British Rail in 1975 (Figure 5). It was perhaps surprising for a product designer, usually working on small machines such as sewing machines and cameras, to find himself involved in the design of such a major engineering product, but again the example illustrates Kenneth's functional approach and eagerness to do what seems necessary, rather than just what is asked for.

The High Speed Train (HST) was developed within British Rail as a kind of internal rival to the much-vaunted, radical Advanced Passenger Train (APT) being developed at the same period, which used revolutionary new technologies such as tilting carriages to increase running speeds. The APT eventually failed altogether, whereas the HST, using evolutionary developments of conventional engineering (and some APT innovations), became hugely successful and, in its 1973 prototype version, with the Grange-designed nose cone, set a world speed record for diesel traction of 230 km/h.



Figure 5 *The British Rail High Speed Train (Intercity 125)*

Kenneth recalls that 'They didn't call me up and say, We'd like you to design a locomotive.' It began much more modestly, as a result of some smaller jobs that he had undertaken for the railways, such as re-designing the timetables. After a few such jobs, Kenneth was approached by his British Rail client representative, James Cousins, Head of the Design Department, about 'a paint job, the painting of the outside of a train.' This train was the new HST. 'So I went in to see him and he'd got a model there, and it was a model of a very

crude bullet-nosed train, and he said to me, This is being produced by the Engineering Department at Derby, this is the train they intend to make, but I can't possibly let them get away with this awful paintwork. It had zig-zags on, and so he said, Come back please with a proposal for the painting of this train. I went away and I did that but I also thought, I could improve the shape of this.' The brief, therefore, was for a styling contribution - a paint livery that might improve the appearance of the train. But Kenneth was not satisfied with such a restricted 'styling contribution': he wanted the style to emerge from the function, and so, without telling Cousins, he found an aerodynamicist, and managed to get use of a wind tunnel test facility at Imperial College, London, and began to make a series of models of the front of the train, gradually developing a better, more efficient, overall shape.

'So bit by bit we assembled an evolution of the shape of the train, based upon wind tunnel testing. I then went along to Cousins with this information and I said, Here's some photos of a shape that's not your bullet-nose, but it's a shape that I think is much more elegant, and by the way, here's the paint job. And he went into a meeting with the Board, and when this thing came up on the agenda he said, Here's the model and here's the livery I propose, but we have taken the liberty of doing some preliminary work on the shape; we believe that the shape proposed - nothing to do with the [engineering of the] running gear, with the actual motor, and so on - but we believe the shape actually could be more efficient. And he had wind tunnel photographs and the Engineering Department had never been near a wind tunnel!'

A successful prototype was developed to Kenneth's design, but the story did not end there. 'I had kept strictly within the technical terms of the brief. This dictated a window made of exceptionally strong flat glass, which severely limited its size, and a single driver's seat positioned centrally. But instead of production going ahead with my design, a disagreement arose between the union and management which resulted in a decision to position the driver and co-driver side by side. This had a profound effect on the design, since our aerodynamics, vindicated by the speed record, relied on a smooth flow of air to left and right of the front window.' There was a number of inter-related problems raised by the necessity of providing for two, side-by-side operators at the front of the cab, instead of the one central operator. The central, relatively small window in the prototype would have to be replaced by two windows with a central bar, and the extra window width inevitably flattened the front profile, thus reducing the aerodynamic efficiency. Even when the glassmakers found that a larger, single sheet of the toughened glass could be produced, the aerodynamic problem was still there.

One way of regaining the aerodynamic efficiency appeared to be to elongate and lower the rake of the cab-front, so as to direct more air up and over the top rather than around the sides. But this option was

denied by the technical requirement of providing the engine's buffers at the front, which were located in a fixed position relative to the wheel bogies, and could not be fully enclosed. Train buffers are necessary not, as is often thought, to cushion the train's stop at the end of the track, but for the engine to shunt carriages around in the assembling of complete trains.

Kenneth was unhappy about losing the aerodynamic efficiency, and pursued the matter with the railways' Chief Engineer. 'Credit is due to the Chief Engineer, because I wasn't welcomed by these guys, but to this man's everlasting credit I was sitting in a meeting with him, going over this fact that this new design was not as efficient as the one that they originally bought, and which had already set a world record. But there is no way you can have the geometry and have the wide window and get the same effect, and we were backwards and forwards over this. I suppose I knew that if we didn't have buffers I'd get a different shape, so I said to him, Tell me again, tell me about buffers, how they work; thinking there might be some way I could sleek them in somehow or other. But you see, you've got this great plate and you've got probably fifteen inches of movement on the springs because of the shunting, and all that's got to be on its own stalk, you can't have that inside a housing, really it's got to be outside of the housing. And he said, Well, it is true that with this vehicle, which we've never, ever made before, we've never, ever made a train where the coaches are always attached, with this, of course, they'll always stay coupled. And he said, So if it's always coupled, it can't be used for shunting, and therefore the only thing we need is a hard link. And so he said, So really we don't need the buffers. To his credit he was prepared to say, We've overlooked it. They'd never, ever made a complete train like that before - they made locomotives, and they made carriages.'

Kenneth's perseverance had led to the vital breakthrough. The buffers on this locomotive for a new, permanently-coupled train, could be dispensed with. The aerodynamic efficiency could be retained by diverting the airflow from around the sides to over the top of a sleeker, more stylish, cab front. British Rail had a completely new, modern image, arising from its original request for 'a paint job'.

Design Process and Working Methods

These three examples - the Kodak Vesta camera, the Frister & Rossman sewing machine, and the British Rail High Speed Train - all illustrate Kenneth Grange's approach to design, which seems predominantly to be based on generating style and form from function and use. This seems to be the natural way for him to work, even though his clients sometimes do not realise this, and approach him as a 'stylist'. 'They think,' he says, 'We need a new design, we need a new style. They're sharp enough to realise the style is outdated or whatever, and they assume because of what they have seen that it's a purely artistic thing, it's a fashion thing only to do

with style. I can't get to a solution from that beginning, so I start entirely from the point of view of, can I make the use of the thing better. Eventually, by some extraordinary piece of good fortune, I wind up with a style that they think is terrific and how it got there they are not interested. It does become interesting when we then start to develop it because I find I'm defending bits of the mechanistic process and they don't want me to, particularly the engineers don't want me to!' He says he always has a concern with 'the nitty-gritty' of products and their use - including not only their primary function but also secondary aspects such as their cleaning. And yet he rejects what he sometimes sees in others as 'a highly moral stance where function is all.' There has been a temptation in British design, he says, 'to scorn the elements of style, fashion and pleasure. That, in my view, is the road to righteous boredom.'

His approach to design seems to be rooted in his early experiences of 'learning by doing' - of learning to take apart and re-assemble artillery mechanisms so that he could make the drawings to allow someone else to do it. He also has strong personal motivation and what he calls an 'I can do it' attitude. 'I think there's a bit of me that is a commercial animal I suppose, a bit of me that's certainly an "I can do it" man, under any circumstances. I always say yes, and of course it gets me into trouble!'

Comparisons with Other Studies

A number of studies of highly creative or innovative designers has been published in recent years, and several points of similarity emerge. For example, studies of the racing car designer Gordon Murray (Cross and Clayburn Cross, 1996) and the racing bicycle designer Mike Burrows (Candy and Edmonds, 1996) suggested that personal motivation and an early commitment in life are essential aspects for helping to generate the work ethic which seems to drive such designers. We hear echoes of that motivation and commitment in Kenneth Grange's accounts of his early life and his working habits.

A study of highly innovative engineers by Maccoby (1991) was based on interviews with eight such people, nominated by their peers. One of the observations Maccoby makes especially is the 'systems approach' adopted by these innovative engineers: 'The innovator has a systems mind, one that sees things in terms of how they relate to each other in producing a result, a new gestalt that to some degree changes the world.' This was also a feature found in the approaches of Gordon Murray and Mike Burrows, and it sounds similar to the approach adopted by Kenneth Grange, in his re-perceptions of the problem as given, usually from the user's point of view, and considering the user's overall task for which the product is being designed. This 'systems approach' is evident, for example in the way Kenneth designed the Frister & Rossman sewing machine so as to

facilitate the whole process of sewing, and the maintenance of the machine.

Roy's (1993) study of James Dyson, the well-known inventor-designer of the Dyson 'cyclone' vacuum cleaner, also suggests parallels with the approach of Kenneth Grange and other leading designers. For example, Roy reports that Dyson's approach to design 'depends on getting ideas and solving problems when working with and observing physical objects . . . rather than by drawing or theorizing.' This is similar to Kenneth's 'hands-on' approach to design, actually working with a sewing machine or observing the use of cameras in order to generate ideas for their improvement.

Lawson (1994) interviewed ten highly successful, creative architects. He drew attention to similarities in the working methods of the architects he studied, which we can see also have similarities with Kenneth Grange, such as working in periods of intense activity. Lawson's architects also are characterised by a dedicated sense of purpose, which they share with small, highly-motivated teams of co-workers. There is also a common sense of focussing on a problem so precisely that it can be approached from 'first principles'; as the outstanding engineer-architect Santiago Calatrava is reported by Lawson to say: 'It is the answer to a particular problem that makes the work of the engineer . . . you need a very precise problem . . .' Or as Kenneth Grange says, 'Sometimes you almost have to fabricate the problem.'

Conclusions

This case study reinforces and amplifies some of the observations that have been made in other studies of successful, innovative designers. Their approach involves a particular style of working. Some aspects of this style arise from the designer's personality characteristics - for instance, their personal motivation means that they are steeped in their chosen domain, and they are prepared when necessary to work obsessively at their chosen problem and solution. The working style is based on periods of intense activity, coupled with other periods of more relaxed, reflective contemplation. The innovative designer also likes, perhaps needs, to work with a small team of committed co-workers who share the same passions and dedication.

Beyond these personality characteristics, there are some potentially useful observations to be made about the methods and approaches adopted by successful, innovative designers, and which might perhaps to some extent be transferrable to others. Firstly, there is a tendency to develop a holistic, systems view of the problem, extending beyond the problem as given into aspects or activities that both precede and succeed the central purpose of the product being designed. Secondly, there is an approach to defining or framing the problem to be solved in a fresh, challenging way, and encapsulated

in a clear goal. The goal is set at a high level, with clear objectives, and in direct terms which might even seem to be simplistic. A design concept for this goal is then devised, and the solution details then cascade from the concept, usually drawing upon basic principles of function, engineering and manufacture. Intense work is needed to develop, evaluate and refine the solution details.

Such conclusions might begin to offer guidance for those involved in the management of design activity or the development of methods or tools to support design activity, for those involved in design education, and for designers themselves. Successful designers seem to be too involved with the urgent necessities of their work to want, or to need, to stand back and consider their working methods - they are not used to abstracting what they do into general principles. However, there remain methodological problems of verifying the accuracy or relevance of the analyses that we and others have so far been able to make of the skills of outstanding designers. The difficulties of studying the performance of such people in formal ways may always limit the validity of the analyses, but more studies of expert and outstanding designers might at least lead to an informed consensus about the nature of their skills and how they practise them.

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