Haptics, the Secret Senses; the covert nature of the haptic senses in creative tacit skills.

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Abstract. A group of renowned highly skilled artists were interviewed with regard to day-to-day sensory engagement. Their observations are discussed together with the part played by the senses in skilled manual processes, particularly those that include a significant creative element. Their personal evaluation of the relative importance of these various senses in specific processes is presented and tabulated and the results are analysed with regard to the interaction of vision and the haptic senses. It is concluded that despite initial convictions that vision plays the dominant role, as it may do in subsequent art appreciation, in making such work, much of the significant perceptual information is dealt with pre-consciously via the haptic senses, with vision performing a role as monitor of process progress.

Keywords.Haptic Control, Art, Craft, Tacit Knowledge, Skilled Dexterity, Sensory Collaboration, Creative Process Analysis, Human Factors.

1 Introduction

Given the intimate interaction between the sensory and motor functions of the haptic system, and the sheer complexity of its functioning, it has been shown that much of the sensory information being produced moment to moment is filtered by gating mechanisms within the primary somatosensory cortex and as a rule, is managed at a pre-conscious level. [2] In this respect, haptics may be viewed as a secret sense and its importance to the practicing artist should not be under-estimated.

This paper summarizes certain results of a series of in-depth and informal interviews with a selection of creative makers (artist/designer/makers) who are internationally acknowledged for their skill, proficiency and commitment. The principal criteria for the selection of these specific individuals were as follows.

- Their proven skill and commonly acknowledged eminence as both artists and makers.
- Each works with a material known to be intrinsically problematic and requiring considerable expertise.
- All demonstrate a significant degree of enthusiasm for, and enjoyment of their particular practices. It is considered that this enthusiasm is also a primary factor in their ability to develop their unusually high skill level and the material intimacy implicit within this.
- All have achieved international recognition for their practice, with regard to both their technical skill and their creative originality.
- All have practiced for more than 20 years and had their work purchased for significant private and public collections.
- All are widely acknowledged by their peers and associated professionals

2 Methodology

The applied artists (makers) interviewed in this instance were Neil Wilkin (N.W.), a sculptor and glass blower, Peter Dreiser (P.D.), a glass engraver, Anthony Robinson (A.R.), a sculptor and blacksmith who specializes in hand forging stainless steel, and Diana Hobson (D.H.), a sculptor and pioneer of the re-discovery of 'Pâte de Verre' glass techniques.

The questionnaire upon which the interviews were based was developed to provide consistence of structure and a basis for comparison. It was divided into five sections, each section advancing the thought process of the participant and directing their analytical attention towards the final section of detailed process analysis. This final section of the questionnaire, 'comparison scaling', brought the artists to the point of precise and careful observation of specific processes or tasks together with their assessment of the relative engagement of the different sensory modalities within them. It was anticipated that by this section of the interview, they would have become familiarized with the specific words and phrases and how they were being used, and have developed a reasonable understanding of precisely what it was they were being asked to do in this context.

Participants were asked to nominate a small number of processes, tasks or stages in their making. These precise 'process components' were considered so that comparison could be made between processes since it was anticipated that the sensory balance need not be the same in all cases. Processes such as 'hammering', 'polishing', 'cutting' and 'smoothing ' were given as examples that might be analyzed. It was hoped that this deceptively simple exercise would give rise to a deep analysis and a highly specific, detailed sensory evaluation of a selection of fundamental process actions. Participants were requested to rank each sense on a scale of 1 to 5, in order of perceived significance, 1 being of no importance, 5 being of highest importance. They were allowed to apply the same score to different senses if they judged that they were of equal importance.

Though vision was initially regarded as being dominant in the sensory interaction of production, it was realised that this was not always the case. The effect of the

preconscious and largely autonomic operation of the haptic senses is extremely subtle and often goes unrecognised. Interestingly, all participants in the final stages of detailed analysis of specific processes came to recognise elements of this and began to modify their initial assessments of the role of haptics.

Initially, the participants were read a brief and necessarily superficial description of the five main sensory modalities. Haptic senses were differentiated since regardless of which sensory input produces the process information, the only direct and immediate output is via the haptic channels as motor control. An exception to this may be speech, but generally within the context of making, there are only very specific occasions when this is a relevant factor, an example being N.W. working with and receiving instructions from the artist he was working with. For the most part, whatever one sees, hears, smells, tastes or touches, the response and process progression is generated via the haptic system.

Sensations of smell and taste were discounted in the majority of instances. Even if they were present, they were there only as part of the background environment and it was not felt that they contributed to the making process. An exception to this was D.H. who described the sensations of taste, on her tongue as she worked with hazardous chemicals.

> "I think once you are wired, if you like, then all the senses become more acute and I always think that taste, actually is a protection for me because if I'm using something that isn't good, I suddenly have this taste on my tongue, here." (D.H.)

One can also envisage instances where smell might provide a warning of a problem, for instance working with a material and tool combination that requires a lubricant to prevent the heat of friction from damaging either the cutter or the material. If the lubricant level is insufficient, there will generally be a smell accompanying the rise in heat providing an early warning that more lubricant is required.

Sound was largely discounted as being of any significance for these makers, indeed for A.R., the procedures involved in working stainless steel are in themselves so noisy and potentially damaging to the hearing that he constantly wears ear defenders to protect himself and his ideal working environment unusually shut him out from all sound. For the others, its only recognized role was to provide a warning when the progress of the making might be compromised.

N.W. described a significant role for sound in the context of alerting him to a possible problem.

> "…you crack the iron off the punty, well off the pipe onto the punty, and there's a definite sound when the glass breaks away and you don't think about it when it sounds normal. When it sounds odd, then you use that to look at what's wrong. Why doesn't that sound right?" (N.W.)

In this part of the glass blowing process, the material is hard, rather than in its softer, semi-liquid state and consequently it is only then that it may be likely to produce a sound of this sort. For the majority of N.W.'s work he did not consider that sound was significant.

For P.D. however, sound could convey a much greater variety and depth of information. Again, he works with hard, non-liquid glass whose properties include resonance which not only varies with the shape of the vessel and the thickness of it's wall, but also with its chemical composition. He recounted a story of his training in which the instructor, from his own workplace on the other side of the room could tell by the sound of the copper wheel as it cut, if a student was working on a piece of glass other than that which he had been given. He goes on to describe the auditory characteristics of the glass in more detail.

"… there is a certain sound, you know if you have a larger vessel, there's more resonance and also you can hear if you're nearly through, it's a papery sound. So your ears are constantly used as well, as much as your... if the sound doesn't come into it, then it's very difficult. But it does come into it, so the feel of... the whole body really gets involved." (P.D.)

Although it is often convenient to consider the senses separately in order to study their contribution to perception and process activity, the information conveyed by each modality during material use merges and they work together with no sense of separation. This fact was emphasised when the participants came to examine the roles of vision and touch, senses they all considered to be of the greatest significance in their activities. Their initial descriptions of these functions tended to emphasise the dominance of vision but it became apparent as the interviews progressed, that the role of touch was inseparable, though in a more subtle and pervasive way. Most interestingly in these cases, their judgment of the significance of this sensory interaction also altered as their description progressed. It was also noted that these senses performed very different and complementary roles and that these roles were dependant on the specific process being discussed. Following the author's own analysis of personal practice, [9] the interview structure was partly developed in anticipation of this evolving understanding and to seek to avoid bias towards haptic solutions.

In a general sense, vision was described as having a role connected with judgement, either aesthetic or practical. Touch provided control and this was seen as fundamental in the demonstration of technical skill and the accomplishment of visualisation. It is considered striking that the participants were sufficiently surprised by this observation as to revise their original judgements with regard to the significance of the sense of touch. As previously discussed, much of the activity of the haptic senses occurs at a pre-conscious level and hence goes largely un-noticed and un-remarked as a result. Designing an experimental structure to investigate this can be problematic and has been observed to introduce the potential for experimental bias. [7]

N.W. described the process of "gathering", which is the first stage of glassblowing when the maker puts the tip of the pre-heated blowing iron into the mouth of the furnace and gathers the first "gob" of molten glass onto the tip of the iron ready to blow the first small bubble. No matter what the finished piece of work is intended to be, this is always the first task of the process. He observed,

"…you can see, as you go in and turn, you can see the meniscus, I mean you can see the way the glass, the sort of wave shape it creates on…, the hill that you get as you turn the gather round and the sort of crest of the wave I suppose, that's turning and goes back into the glass

> again, so you get that shape and if it's really runny then you've just got a little bump. Whereas if it's really viscous, you get a long curve and a tight erm… so you can see it all, you don't need touch. But touch is important. I wouldn't put it down at 3 because it's another…, I suppose it is 4 because you'd probably feel it before you saw it. You'd probably feel that it was a little bit viscous. Or not. And then you would look. Oh yeah, right, I can see what I'm feeling. You'd probably feel it first, but the sight would confirm. But if you don't have the feeling then the sight would be enough." (N.W.)

This was the first specific task that N.W. evaluated for sensory contributors, and his initial focus was on vision though it can be seen that it did not take long for him to realise that touch, whilst less obvious, was of great importance. At this point however, he was still of the opinion that touch, whilst useful, was not absolutely vital. He said,

> "…Bit chicken and egg, that one. But you can cut out the touch, you couldn't cut out the sight." (N.W.)

He then went on to describe the task of shaping the bubble with a pad of wet newspaper held in the cupped hand. This technique originally came from Sweden and has become a fundamental in studio glassmakers practice. It is very direct and as near to shaping the molten glass directly with the hand as possible. As he described how this works, his insight of how touch and vision collaborate began to alter, though again, his initial response was to examine vision. He said,

> "Well, sight is very important because you have to look at what shape you're starting with and then know what…, what you've got to do to it. You look at what you've got, you know what shape you're trying to make, so then you know which bit has to be narrower or wider. So, sight is important for looking at what you have and what you've got to do. Sound isn't important at all, nor is smell or taste. But the feel of it is…, how it responds and if it doesn't move, if it feels rock solid then you know you've got to go and reheat it." (N.W.)

The temperature of the glass at this moment is clearly critical to the success of the process and the visual qualities of the glass as it changes colour do not convey sufficiently accurate feedback of this. N.W. went on to say,

> "You'd probably feel it first, you'd probably feel that it's still soft before you see that it's moving where you want it to move or you've got to move it further. So you probably feel it and then squeeze, either respond by squeezing harder or not squeezing so hard. I would imagine you get that response back first, before visually you see and make a decision. As though the hand is quicker than the eye, you know it's the magic, you can feel it and it takes a little bit of time to interpret what you see. But you look at it, and see the shape that it is and squeeze to adjust the shape. In other words you use the paper to adjust the shape and you see what's happened and then, you then squeeze harder if you need to and you want to push it a little bit further." (N.W.)

He had realised by this point, that the sensory response was considerably more to do with haptic senses in this procedure than vision, which took a subordinate role as arbiter of judgement as to whether the form was proceeding correctly to the end originally visualised. His awareness of these developing sensory functions continued to increase as his description progressed.

"The decision is made by…, visually, as it moves into the right shape but the actual response of squeezing and then squeezing harder or softer is almost certainly a physical… you know, you squeeze it and see what you've just done. It's got to go all the way round before you can see that you've…, what shape you've changed, because you're only seeing it from one view. So you have to do a full revolution to see, is there an answer? Yet when you squeeze, it's the moment you put a little bit of pressure on and you feel whether it is giving or not. So that kind of confirms it. How hard you squeeze is how it feels before anything else." (N.W.)

N.W. was then asked if this factor was critical in accurately achieving the desired form. This is considered central to the definition of skill and the development of expert control in making processes. His response was particularly interesting.

"Yes, because if you, if you've got to wait until you can see that you've done it wrong, it's too late. Well, it wouldn't be if you'd got it right, but it's too late to then say, oh, I pushed it too hard and let it go whereas if you go on, you can reheat it and take the pressure off before you make it narrower all the way round so just putting a little dent, which by the time you get round it's moved again. So perhaps, perhaps that was a 5. Mmm… touch. I may be going back on what I said earlier." (N.W.)

At this point, N.W. had realised a key fact. Much of the role of the haptic senses goes un-noticed and hence, un-remarked in our lives, dominated as it is by the more immediately apparent role of vision. When we listen to an orchestra playing a symphony, our immediate attention is generally drawn to the part played by the soloist. Other orchestral parts are perceived more peripherally and only gradually by focussing our attention do their functions and characters become apparent. That their role is vital to the performance as a whole is undeniable, and it is clear that a solo recital is of a very different order to a full orchestral concert. N.W.'s experience of examining his own highly developed and skilled practice clearly illustrates the similar function of the haptic senses and the pervasive and vital position that these senses take in our making activities and perhaps our lives in general.

A similar, though marginally less dramatic revelation occurred to A.R. during his evaluation of specific task processes. At the start of this part of the interview, he was asked, "Would you say then, that sight and touch are equally important?" His reply was clear and unequivocal, "Yes! They complement each other". However, subsequent questions revealed that certain processes tended to accentuate vision, and as in the case of N.W., the role of the haptic senses appeared subordinate. Again, vision was fundamental in the role of judgement of process progress and truth to conception, and the haptic senses provided control though again, this was not considered particularly remarkable. Discussing the overall significance of the various senses in the example activity of grinding down a piece of metal, a regular part of his particular practice, he was asked if haptics and vision were still of equal importance and described it thus,

"it's not so marked because your sight is the most important thing because you're removing metal to a given dimension or a line or shape, you're taking a line down to a shape so the actual tool..., you do get a sensation of removing metal with a decisive tool. It's just a means to end. Your sight is 95 percent of the operation and it's telling you whether you've done enough." (A.R.)

Following this, he described the task of polishing a piece of stainless steel and in doing so unconsciously described vision and touch together almost as the same thing. Though he still, at this point regarded vision as most significant since it's input was conscious, the predominant underlying sensation he described was haptic.

"The important sense there, is actually watching this..., you tend to get absorbed in this tiring, pushing sensation of muscular strain so that it becomes a norm at that time when you're doing it and that's the level of your..., live with the moment. So it's vision, you're looking at the surface, you're monitoring the surface finish." (A.R.)

A little later however, he evaluates this process in more detail and it becomes clear that the activities of the haptic senses are of far greater complexity and in reality, the process progress depends largely on these senses, with vision as arbiter, which can be regarded as a more ancillary, though no less vital role in this context.

"So you're pushing the material up against the polishing wheel which is spinning away, it's abrading the surface and you are watching the surface, you're constantly checking every couple of seconds, you check, you check, you make a pass over the wheel and you check it, again and again, and you know how much you must…, you're getting a feel for how much more you must push on to it. You can't push too heavy, otherwise you'll stall the motor and so it's like driving a car on ice, or on a slippery surface in the wet. You know how much throttle you need and how much you don't need, you know, and it's gaining grip, you're losing grip and you're watching the surface appear from underneath and you just, you just keep drifting with it. And you can ease off, you can press on and ease off and press on as you feel it needs it. It tells you what it wants next." (A.R.)

This seems a classical description of the body's immediate and unconscious response to moment-by-moment haptic feedback and with a few minor contextual changes, it could be applied to a great many human activities. It also clearly illustrates the closely connected roles of vision and touch and their relative responsibilities within the process. Vision is there as a monitor of progress, but the haptic senses have primary responsibility for facilitation and their activities are extremely complex.

A.R. was pressed at this point to define which of these senses was most deeply implicated in his perception that the piece of stainless steel "tells you what it wants next." Again, it seemed very difficult for him to separate their influences. He said,

"No, there are certain..., yeah, I mean to get right into the heart of it..., it's how it looks. But you can feel! You can feel when the polish comes round that it's being used up and then you can put more on. And you can feel, you can feel when it's biting. There are certain conditions when "ah I've got it, I've got it ", you know. It's all happening within seconds, split-seconds, constantly." (A.R.)

This split-second repeating loop of information input and feedback response suggests a predominantly haptic situation and this author's experience suggests that this is typical of expert making skills. Responses of this type have been shown to occur faster than conscious thought or visual processing in the brain.[3,1] A.R.'s description may therefore indicate that his responses are occurring at the level of a cerebral reflex. [11] Given the wealth of A.R.'s professional skill, it seems likely that this would take the form of a conditioned or learnt reflex.

A.R. then proceeded to describe the immediacy of this process experience and in doing so, touches both on the specific mechanisms implicated in the development of such tacit knowledge and the deep satisfaction produced, which is considered so significant in the motivation of creative makers. He indicated that such experience is non-cognitive in nature, implicating sub-cortical mechanisms and neurological haptic functions in this type of knowledge.

"Yeah, and it's very immediate! And you can feel..., as and when you need to add more compound, in your limbs you know that you should be pushing, so two or three times, more compound, two or three times, more compound, another two or three times, more compound, and then you work out this technique where you push on the work and ease back, in reciprocating motion so you're bringing a pulse, as it were, against the wheel and it's then, what it does is it..., it..., you're using the maximum revs because the wheel always slows down a bit and the initial maximum revs, you get maximum cut so it takes most off and then it eases off a bit. … There is nothing ordinary about this, this polishing, I mean I can't stress it too much really, there's nothing ordinary about it. And if you're tired, you don't bother because you'll make a mistake. (Pause) It frees your mind up, anyway." (A.R.)

In the final stages of the interview, the participants were requested to select a particular process or a specific task within a longer process and comment on the relative importance of the implicated senses. The overall results of this comparison are summarised in Table 1.

Table 1. Sensory scoring for all nominated tasks.

PROCESS	SIGHT	TOUCH	SOUND	SMELL	TASTE
Roughing Out	4	5	3	1	1
Polishing	4	5	3	1	1
Hammering	5	5	1	1	1
Drawing / Laying Out	5	1	1	1	1
Grinding	3	3	5	4	4
Surfacing	5	5	4	1	1
Modelling	5	5	4	1	1
Aesthetic Development	5	1	1	1	1
Gathering	5	4	1	1	1
Shaping with Paper	5	5	1	1	1
Shaping with Tweezers	5	3	1	1	1
Blowing Bubble	4	5	1	1	1
TOTAL SCORE	**55**	**47**	**26**	**15**	**15**

The scoring results presented are not considered statistically significant. The interviews were constructed with the intention of eliciting observations and significant indicators of sensory factors in making, rather than empirical results and

the questionnaire structure was intentionally imprecise in this respect. Additionally, the sample size of only four participants was so small as to make statistical analysis scientifically meaningless. However, it is suggested that the system of scoring and particularly the comparison of scores between specific tasks can be considered indicative.

It was noted that vision scored highest overall for this particular group of tasks, but the haptic senses were considered by the participants to be inseparable from this and were rated almost as highly. For seven of the twelve specific tasks nominated, touch was given the top score of 5. By comparison, vision achieved a top score in eight of the twelve tasks, however two of these, namely drawing/laying out and aesthetic development might more correctly be considered preparatory or visualization tasks rather than actual making processes, though the participants rightly regarded them as integral to their overall practice. Although the author considered at the time of the interviews that these two particular nominated tasks did not fall strictly into the area under research, namely 'Haptics in Making Processes' it was decided that to interrupt the flow of reflection at this point might disrupt the procedure and the participants descriptions of these tasks was allowed to proceed. This author acknowledges that the cognitive aspects of planning are of great importance to the overall practice of art and would seem to be essentially linked with vision, whilst touch may appear to play a less significant role in this type of activity. Interestingly, if these two preparatory visualization tasks are removed from the comparison table, we see that that the overall association picture changes (Table 2).

Table 2. Sensory scoring for making tasks only

PROCESS	SIGHT	TOUCH	SOUND	SMELL	TASTE
Roughing Out	4	5	3	1	1
Polishing	4	5	3	1	1
Blowing Bubble	4	5	1	1	1
Hammering	5	5	1	1	1
Grinding	3	3	5	4	4
Surfacing	5	5	4	1	1
Modelling	5	5	4	1	1
Shaping with Paper	5	5	1	1	1
Gathering	5	4	1	1	1
Shaping with Tweezers	5	3	1	1	1
TOTAL SCORE	**45**	**45**	**24**	**13**	**13**

In this case, vision and touch achieve exactly the same total score however touch scores higher than vision for three of the tasks, (indicated in dark grey), scores equally for a further five tasks, (indicated in mid grey) and is ranked as less important than vision for only two tasks (indicated in pale grey) out of a total of ten. The tasks have

been re-ordered to reflect these groupings and illustrate that the role of touch is actually considered of equal or higher significance to vision in eight out of ten instances as compared to vision being considered of equal or higher significance in seven out of the ten, despite the participants' initial conviction that vision is predominant.

The comparison of the scoring with and without these two tasks may indicate that there are distinctly different sensory weightings between creative making and other creative (though perhaps more predominantly cognitive) tasks such as drawing or aesthetic development. Though overall, vision was described as being dominant, with touch being of lesser significance, the participants scoring for the making tasks in Table 2 indicate that in actuality, touch was of at least equal significance to vision. Given the noted covert, pre-conscious character of the haptic senses, which might be expected to result in a general marking down of their scores, the author considers this result to be of great significance. It is indicative that haptics is indeed of fundamental importance in certain types of creative activities and further that this importance is generally unacknowledged and unrecognized by artists and researchers alike.

3 Conclusions

Gradually acquired tacit knowledge seems to be almost never analysed, except perhaps, when one is required to teach the skill to others. It also seems that a fundamental of tacit skill relates to the ability to engage in the process with a minimum of high-level cognitive processing. This concept has been described as 'transparency' and in the context of manual skill and acquired expertise, it is suggested that any cognitive processing that is involved is performed differently, as a separate element of the procedural 'flow'.

This seems particularly true of those fundamental elements of sensorimotor skill, where haptic processing occurs predominantly at a pre-conscious level. It is suggested that this may be linked with findings identifying two distinct streams of visual information in the brain; the ventral being concerned with cognitive and perceptual information and the dorsal which is concerned with moment-to-moment visual control of action. Goodale et al [4,5]

The field research summarized here provides confirmation of certain ideas that arose from the author's own observations of personal practice and raised a number of new issues. [9] It became apparent over the course of the interviews that much of the functioning of the haptic senses goes un-noticed and hence, un-remarked in our lives, dominated as it is by the more immediately apparent role of vision. This seemed initially somewhat strange in this context since those being interviewed were all internationally respected artist/makers, known as much for the excellence of their technical expertise as for their artistic concepts. One might perhaps have expected people who were so closely engaged on a day-to-day basis with manual dexterity and control to have been overtly and consciously aware of how much sensory information was provided by the haptic channels and its significance in their practice. Though it may be said that on a perceptual level the operations of any of the senses may be regarded as working in this way, (only when the conscious attention is focussed on a

particular sense do its operations become apparent), there appeared to be something rather different going on in this instance. The analysis of the progression of transparency associated with manual skill development described in Prytherch & Jerrard, [9], may provide a partial answer. The analysis observes that as the development of manual expertise progresses, the level of tool and material transparency is also experienced as increasing.

If we remember the experience of learning to ride a bicycle, initially all the bodily movements of control and balance must be concentrated on. As we become more proficient, this awareness recedes and whilst it is still possible to focus one's attention on, for example balancing or steering, this may be likely to have a detrimental effect on overall performance by acting as a distraction and disrupting the harmony of physical co-ordination. We may still however focus the attention of any of our other senses, vision hearing, smell or taste without any adverse effect on our activity. Indeed, in many instances, we must do precisely that, for example, we must focus our vision on where we are going whilst riding our bicycle or on the tip of the brush and its contact with the paper whilst painting. This concentration of attention seems necessary in these instances, but it appears that the opposite is true for our haptic modality. For the haptic senses, it seems that as we become more proficient, we must learn, in some ways to concentrate and focus our attention less, rather than more. The haptic senses would appear in many ways to function most efficiently when we become sufficiently adept that we can relegate them to our perceptual background. These observations link closely to the "*successive organisation of perception* (SOP)" theory, proposed by Krendel and McRuer, [8] based on their tracking skill research, more recently reviewed by Jagacinski and Hah, [6] and further discussed in the context of haptic interface control systems by Zhai, [12].

This inherent association of the senses, particularly the close intimacy between the haptic senses and sight perhaps gave rise to the artists initial conviction that sight was the primary activator. However, on further reflection, the role of the haptic modalities began to become more apparent. Largely, the participants were surprised by this unexpected realization and were constrained to re-evaluate the nature of their sensory involvement.

4 Summary

- The haptic senses are of fundamental importance, particularly in certain types of creative activities and this importance is generally both unacknowledged and unrecognized by artists and researchers alike.
- Though vision is generally considered the most significant and dominant sense initially, a deeper practice analysis reveals that the haptic senses are at least as critical as vision, which appears to function primarily as a monitor of process progress.
- For the haptic senses, it seems that as we become more proficient, we learn in some ways to concentrate and focus our attention less, rather than more. The haptic senses would appear in many ways to function most efficiently when we become sufficiently adept that we can relegate them to our perceptual background.

References

1. Carlton, L. G. (1992). Visual ProcessingTime and the Control of Movement. In Proteau, L. and Elliot, D., *Vision and Motor Control, Advances in Psychology* (85, 3 - 31). Amsterdam North-Holland: Elsevier Science Publishers.
2. Chapman, E. C., Tremblay, F., & Ageranioti-Bélanger, S. A. (1996). Role of Primary Somatosensory Cortex in Active and Passive Touch. In Wing, A.M., Haggard, P. & Flanagan, J.R, *Hand And Brain, The Neurophysiology and Psychology of Hand Movements* (329 - 347). London: Academic Press.
3. Glencross, D. J. (1977). Control of skilled movement. *Psychological Bulletin, 84,* 14 - 29.
4. Goodale, M. A., & Millner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences, 15,* 20 - 25.
5. Goodale, M. A., Jakobson,L.S., & Servos, P. (1996). The Visual Pathways Mediating Perception and Prehension. In Wing, A.M., Haggard, P. & Flanagan, J.R, Hand And Brain, The Neurophysiology and Psychology of Hand Movements (15 - 31). London: Academic Press.
6. Jagacinski, R. J., & Hah, S. (1988). Progression/regression effects in tracking repeated patterns. Journal of Experimental Psychology: Human Perception andPerformance, 14 (1), 77-88.
7. Klatsky, R. L., Lederman, S. J., & Reed, C. (1987). There's More to Touch Than Meets the Eye: The Salience of Object Attributes for Haptics With and Without Vision. Journal of Experimental Psychology: General, 116 (4), 356-369.
8. Krendel, E. S., & McRuer, D. T. (1968). Psychological and physiological skill development - A control engineering model. Proceedings of the Fourth Annual NASA-University Conference on Manual Control (Sp-192), Ann Arbor, MI: NASA.
9. Prytherch, D., & Jerrard, R. (2001). The Visualisation and Making of Sculpture and it's Potential Implications for Computer Interfaces and Three Dimensional Modelling. In Eds. Baber,C., Faint, M., Wall, S., & Wing, A.M, Proc. Eurohaptics 2001. pp. 135-137. Birmingham:. (ISSN 1463-9394)
10. Prytherch, D. (2003). Haptic Feedback in Art Making Processes with Particular Reference to Computer Interface Design. PhD Dissertation, Birmingham Institute of Art and Design, University of Central England in Birmingham.
11. Wing, A. M., Haggard, P., & Flanagan, J. (Eds.). (1996). Hand And Brain, The Neurophysiology and Psychology of Hand Movements. London: Academic Press.
12. Zhai, S. (1993). Investigation of Feel for 6DOF Inputs: Isometric and Elastic Rate Control for Manipulation in 3D Environments. , Proc. The Human Factors and Ergonomics Society 37th Annual Meeting.