# A comment, a case history and a plan

Gordon Pask

*'Man is always aiming to achieve some goal and he is always looking for new goals.' (Pask)*

This article was written prior to the Cybernetic Serendipity exhibition (ICA 1968) and is unaltered. The appendix was added later in 1968.

**A comment on the cybernetic psychology of pleasure**

Man is prone to seek novelty in his environment and, having found a novel situation, to learn how to control it. Let us develop and qualify this cybernetic statement. In the symbolic domain which constitutes the most important aspect of the human environment, 'novelty' inheres in events or configurations that appear ambiguous to a given individual, that engender uncertainty with respect to his present state of knowing and pose problems. 'Control', in this symbolic domain, is broadly equivalent to 'problem solving' but it may also be read as 'coming to terms with' or 'explaining' or 'relating to an existing body of experience'. Further, when learning to control or to solve problems man necessarily conceptualizes and abstracts. Because of this, the human environment is interpreted at various levels in an hierarchy of abstraction (on the same page we see letters, words, grammatical sentences, meaningful statements and beautiful prose). These propensities[1] are at the root of curiosity and the assimilation of knowledge. They impel man to explore, discover and explain his inanimate surroundings. Addressed to the social environment of other men, they lead him into social communication, conversation and other modes of partially co-operative interaction.

To summarize the issue in slightly different words, man is always aiming to achieve some goal and he is always looking for new goals. Commonly, he deals with goals at several levels of an hierarchical structure in which some members are freshly formulated and some are in the process of formulation. My contention is that man enjoys performing these jointly innovative and cohesive operations. Together, they represent an essentially human and an inherently pleasurable mode of activity.

This dogmatic statement of the human condition does not apply in all circumstances. On occasion, perhaps, men are vacuous. On occasion, they merely respond to stimuli or act as passive receptors. But the characterization is accurate enough whenever a man is involved in aesthetic activities, which include:

1 Organizing a bit of symbolic environment by constructing a tangible work of art (e.g. painting a picture).
2 Writing a prescription which is interpretable as a work of art (e.g. composing music and writing the score).
3 'Performing a work of art' or, strictly, 'interpreting a work of art prescription, such as a piece of music'.
4 Appreciating or enjoying some work of art.

It does not seem useful to make a rigid distinction between the types of mental process that go on when a man occupies these different roles: 1, 2, 3 and 4. The composer is, in some sense, mentally akin to the performer and listener; the man who views a picture is mentally akin to the artist who painted it.

With all this in view, it is worth considering the properties of aesthetically potent environments, that is, of environments designed to encourage or foster the type of interaction which is (by hypothesis) pleasurable. It is clear that an aesthetically potent environment should have the following attributes:

*a* It must offer sufficient variety to provide the potentially controllable novelty required by a man (however, it must not swamp him with variety—if it did, the environment would merely be unintelligible).

*b* It must contain forms that a man can interpret or learn to interpret at various levels of abstraction.

*c* It must provide cues or tacitly stated instructions to guide the learning and abstractive process.

*d* It may, in addition, respond to a man, engage him in conversation and adapt its characteristics to the prevailing mode of discourse.

[1] My 'propensities' have been adumbrated under various titles. Bartlett speaks of a 'search for meaning', Desmond Morris of a 'Neophyllic tendency', Berlyn of a 'curiosity drive' and Bruner of a 'will to learn'. My own writing credits man with a 'need to learn'. Social psychologists, such as Argyll, have essentially the same concept. So do the psychiatrists. Here, the point is most plainly stated by Bateson, and by Laing, Phillipson and Lee.

The aesthetically potent environments discussed in this paper are reactive and adaptive. They go *some* way towards explicitly satisfying the requirements of *d*. However, *any* competent work of art is an aesthetically potent environment. Moles has pointed out that its information structure is tailored to suit *a*, *b* and *c* (among other things, this is why a play or a symphony bears repetition). Condition *d* is satisfied implicitly and often in a complex fashion that depends upon the sense modality used by the work. Thus, a painting does not move. But our interaction with it is dynamic for we scan it with our eyes, we attend to it selectively and our perceptual processes build up images of parts of it. Further, consciously or not, the artist anticipated this dynamic interaction (if only because he looks at the picture himself). Of course, a painting does not respond to us either. So, once again, it seems deficient with reference to *d*. But our internal representation of the picture, our active perception of it, does respond and does engage in an internal 'conversation' with the part of our mind responsible for immediate awareness (this is probably the most important consequence of Moles' insistence upon perceptual 'quantization', though he does not make the point in this way).

With suitable qualifications, precisely the same comments apply to works of art (like plays and musical pieces) that are presented in a sequential or partially sequential fashion. In each case, the external aesthetically potent environment gives rise, bit by bit, to an internal representation and the reciprocal interaction of *d* is internalized as a discourse between the internal representation and our immediate selves. In contrast, a reactive and adaptive environment is intended to externalize this discourse.

A couple of questions arise. First, is there any special advantage to external (rather than 'internal') discourse or, by the same token, to reactive and adaptive environments? Next, supposing there is, can it be done?

The latter question can be answered in the affirmative. The former, cannot, so far as I know, be answered at the moment. The chief merit of externalization (apart from the scientifically interesting fact that externalized discourse can be observed, whereas internal discourse is unobservable) seems to be that external discourse correlates with an ambiguity of role. If I look at a picture, I am biased to be a viewer, though in a sense I can and do repaint my internal representation. If I play with a reactive and adaptive environment, I can alternate the roles of painter and viewer at will. Whether there is virtue in this, I do not know. But there might be.

Rather than indulge in a theoretical discussion of reactive and adaptive aesthetically potent environments, I shall present the case history of one and the plan for another. The case history refers to a system called Musicolour which, though workable, suffered from a number of defects. It is closely related to Professor Lerner's well conceived system Colour Music (presented at the Soviet Exhibition in London, 1961), to the fascinating work of Nicolas Schöffer and to various artifacts shown in the USA. Previous accounts of the Musicolour system have concentrated upon its technical aspect. In the present paper, I shall try to give a glimpse of the historical circumstances, since these are relevant to the development of any similar cybernetic system. The plan refers to a project (called a 'colloquy of mobiles') which is a design for an aesthetically potent environment of a sociological type. Although it is a new departure, it relies heavily upon lessons learned in connexion with Musicolour.

### A brief case history of the Musicolour system

The Musicolour system was inspired by the concept of synaesthesia and the general proposition that the aesthetic value of a work can be enhanced if the work is simultaneously presented in more than one sensory modality. This notion is old enough. Baudelaire played with it in 'Les Fleurs du Mal'. Scriabin wrote a part for a 'light keyboard' in one of his symphonies and Kleine (among others) realized a 'light keyboard' in the metal. Walt Disney's *Fantasia* (1940) is a synaesthetic film. Nowadays, when psychedelic effects are commonly synchronized with music, the whole idea of augmenting sound by light is almost as banal as another happening. However, it was not so in the early 1950s.

The first Musicolour machine was built and demonstrated by McKinnon Wood and myself at Jordan's Yard, Cambridge in 1953. It was a transducer which accepted a musical input through a microphone (this input is conveniently formalized as the performer's selection from an auditory vocabulary). The output of the transducer consisted in a selection made from a predetermined vocabulary of visual symbols; coloured forms which were projected on to a large screen in front of the performer and an audience. Even the first machine contained one refinement. We realized[1] that if a synaesthetic relation does exist (for example, if high notes suggest puce splodges) then it almost certainly differs between individual performers. Hence, the machine incorporated a rudimentary learning facility able to modify the relation of the auditory vocabulary to the visual vocabulary as a performance went on.

The development of the system, in particular the specification of what constitutes a visual symbol, owes a great deal to Valentine Boss. At gatherings of the Pomegranate Club (an eclectically Dadaist organization which he founded) it was possible to experiment with Musicolour and to observe its effect upon moderately sized groups of people. In the same spirit we also showed the system in a bizarre and eventful tour of the north country, at Liverpool, New Brighton and Llandudno. On the whole, Musicolour elicited favourable comments. Hence, towards the end of the year, we decided to shift our base of operations from Cambridge to London.

By that time it was clear that the interesting thing about Musicolour was not synaesthesia but the learning capability of the machine. Given a suitable design and a happy choice of visual vocabulary, the performer (being influenced by the visual display) could become involved in a close participant interaction with the system. He trained the machine and it played a game with him. In this sense, the system acted as an extension of the performer with which he could co-operate to achieve effects that he could not achieve on his own. Consequently, the learning mechanism was extended and the machine itself became reformulated as a game player capable of habituating at several levels, to the performer's gambits.[2] Nevertheless we retained the name 'Musicolour' and the theme of sensory transduction because they subserved the financial necessity of marketing the system as an entertainment device. We hoped, also, that an audience would become involved in the very real interaction between the performer and the machine. At Pomegranate happenings, this seemed to occur, but probably because the audience were thoroughly involved in the performance. Subsequent attempts to engage the audience in the performer–machine feedback loop gave disappointing results, though the machine consistently had an almost hypnotic effect upon the performer.

By this time also, the scale of the equipment had been enlarged. Experience in Cambridge showed that a picayune display was utterly ineffective. In practice, it was necessary to modulate between 35 and 50 kW of lighting. The apparatus required for this purpose occupied a couple of motor vans and a team of five people was needed to set up for a one-night stand.

A system of this magnitude was installed at Dr Richard Cook's studio in Gunter Grove, London. It was a beautiful barn of a place, built by Alma Tadema, with a north light that frosted over in winter. It contained a grand piano, a stove that either got red hot or went out and a cosy assortment of 1920s reading lamps. For a year or so this was our permanent base.

At this point, the mechanical and electronic essentials of the system were fully evolved. Let us pause to look at them. An outline of the system is shown in figure 26.

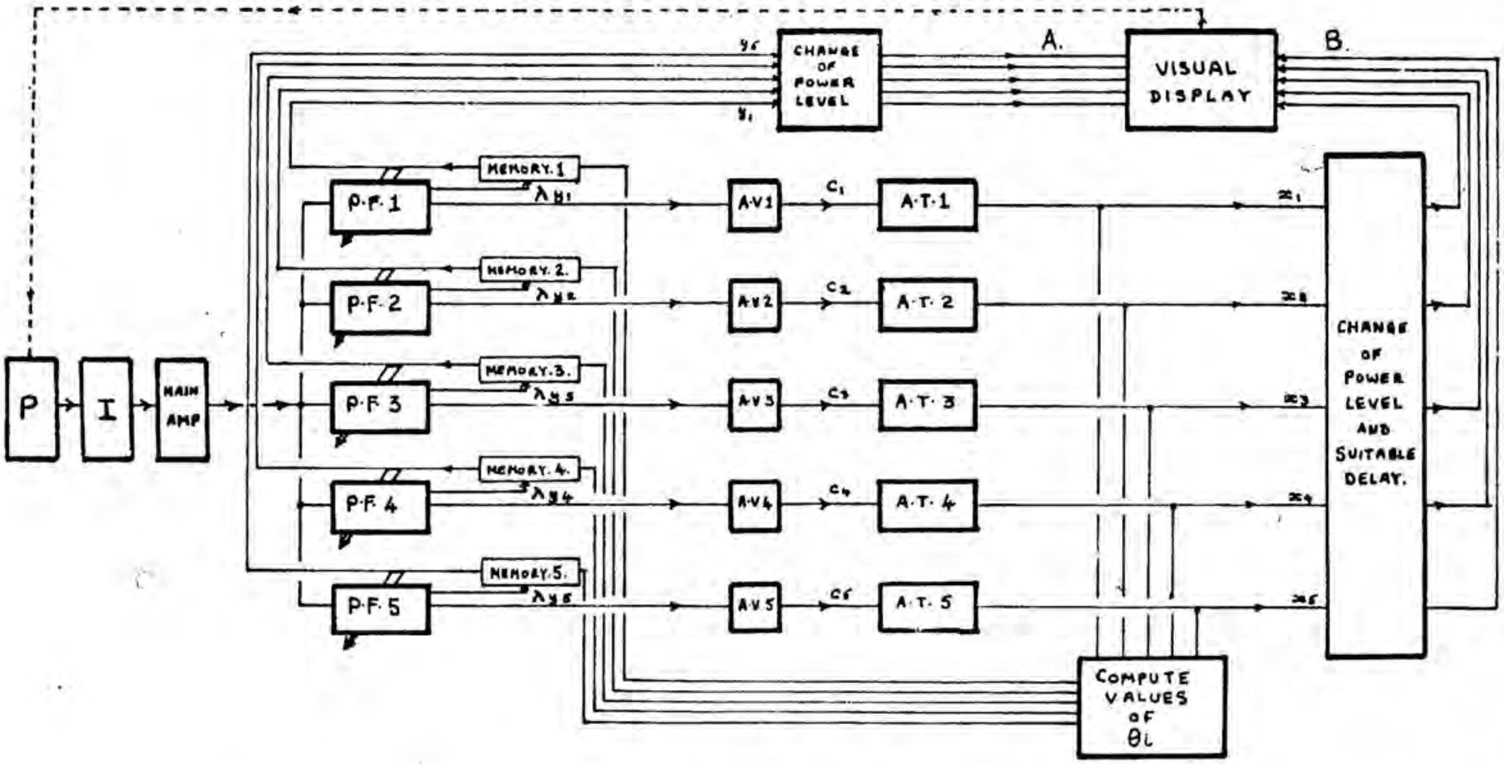
The musical performer (who may, incidentally, be replaced by a small group or band) must first be able to see the visual display and second be able to modify his performance according to what he sees. The latter condition can be satisfied in various ways. At one extreme, the performer has a (usually memorized) score and he modifies his performance by giving a different interpretation to the piece. At the other extreme, he improvises in a fashion that is only constrained by the canons of music and his own disposition.

The musical sequence is picked up by a microphone and amplified. The resulting electrical signal is presented to a bank of property or attribute filters which 'listen to' the sequence. The characteristics of these filters are changed by an internal learning process; technically, their parameters are adjusted. Hence the machine can 'listen to' the perform-

[1] 'We' or 'I' represents Sheila McKinnon Wood, Elizabeth Pask, T. R. McKinnon Wood and myself, together with our immediate collaborators, notably John Brickell and Jone Parry. Rightly, this part of the article should be dedicated to Jone Parry, the musical director, who died while it was being written. Even in the hectic conditions of development and commercial exploitation, Jone worked on the system to produce an art form.

[2] Such a device has much in common with Nicolas Schöffer's artifacts which I learned about many years later.

Fig. 26 Outline of a typical Musicolour system. $P$ = Performer, $I$ = Instrument and microphone, $A$ = inputs, $y_i$, to visual display that specify the symbol to be selected, $B$ = inputs, $x_i$, to the visual display that determine the moment of selection. $PF$ = property filter, $AV$ = averager, $AT$ = adaptive threshold device. Memories hold values of $(y_i)$ and $(y_i)$. Control instructions for adjusting the sequence of operation are not shown. Internal feedback loops in the adaptive threshold devices are not shown.




ance in different ways; the machine-learning process is chiefly a matter of learning to listen.

There could be up to eight different property filters, each with an independently adjustable parameter. In the system shown in figure 26, there were five only. Again, the properties could be chosen in various different ways; for example, in the earlier machines we used only frequency band pass filters (the parameter value determining which pass band the filter listened to). For the system of figure 26, primarily designed to suit piano music, the five properties were, (1), (2), (3), frequency filters operating between 50 and 7500 cps (the parameter value for anyone determining the location of the band pass maximum in this range); (4) a transient detector and (5) a fairly complex rhythm detector.[1] The parameters of filters (4) and (5) were delay operators. To complete the description, each parameter could assume one of eight possible values at a given instant.

The electrical output from each filter is now separately rectified and short term averaged. The resulting signals are designated $c_i$ (fig. 26), the subscript $i = 1, 2, 3, 4$ or $5$, indicating the name of the associated property filter. $c_i$ is next presented to an adaptive threshold device. Such a device emits an output impulse (designated as $x_i = 1$) if its input, $c_i$, exceeds some threshold value, $T$; failing this, $x_i = 0$. To render the circuit adaptive, we arranged that the value of $T$ would decrease at a fixed rate when $x_i = 1$ and that it would increase at a fixed rate if $x_i = 0$. Hence, the circuit automatically adjusts its sensitivity to the mean value of $c_i$ and adapts.

The 5 variables, $x_i$, are one output from the machine (they determine when a selection is to be made from the visual vocabulary). The other output consists in 5 variables, $y_i$,

[1] The circuit detects a beat in the music. Given a beat, it estimates when the next beat will occur on the basis of its previous experience and an internal counter that selects which beat in a short sequence this is. The filter output is high valued if its estimate is right.

which are identical in value with the settings of the filter parameters (the $y_i$ determines which visual selection is to be made).

The learning mechanism in figure 26 sets the values of the $y_i$. The filter parameter values are changed by motor-driven switches (carrying several banks of contacts but with 8 positions, corresponding, in the case of the $i$th, to the 8 values of $y_i$). Each contact position is associated with a pair of 'memory' circuits. One of these retains a record of how long it is since this position was last selected (call this quantity $\lambda(y_i)$ for reference; its value is set to 0 when the switch position is occupied and increases otherwise). The other 'memory' contains a record of a selective figure of merit (for the $i$th property filter with a particular parameter value), designated $\theta(y_i)$. This quantity depends upon a 'figure of merit' variable, $\theta_i$, which is associated with the filter alone (irrespective of the parameter value) in the sense that $\theta(y_i)$ is incremented or decremented towards the prevailing value of $\theta_i$ on those occasions when the switch is in the given position (i.e. when $y_i$ has a particular value). Now, at a specific instant, $\theta = R_i$ [Time average $(x_i)$], where $R_i$ is a rough measure[1] of the difference (in the immediate past) between the impulse sequence from the $i$th threshold circuit and the four other impulse sequences. Hence, $\theta_i$ is high valued if $x_i$ is often in state 1 *and* if the $i$th impulse sequence is idiosyncratic. $\theta(y_i)$ is high valued if these conditions are satisfied for a particular switch position or value of $y_i$.

The parameter switches are driven by their motors according to a strategy that seeks a high figure of merit and also guarantees (through the use of the $\lambda(y_i)$) that all of the switch positions are sampled. The strategy is: if the $i$th switch has selected position $y_i$, remain there for at least a preset minimum interval (about five seconds); otherwise inspect the $\lambda(y_i)$ and the $\theta(y_i)$ and move to whichever position corresponds to a maximum of $\lambda(y_i) + \theta(y_i)$ (if there are several maxima, one is selected by an arbitrary rule).

Applied to each of the switches, the strategy determines the instantaneous values of the 5 variables, $y_i$.

[1] The measure is obtained by generating for each transition $(x_i = 0) \rightarrow (x_i = 1)$ a positive going, exponentially damped, waveform $\phi_i(t)$ and simultaneously generating its negative going complement $-\phi_i(t)$. $R_i$ is the output of an averaging circuit with a fifteen-second time constant that receives $\phi_i(t)$ and four different waveforms $\frac{1}{4} - \phi_j(t), j \neq i$ as its input. If the impulse sequences $x_i(t)$ are identical, all $R_i$ become 0. The deviation of $x_i(t)$ is roughly indicated by an increase in $R_i$.

Such a system 'gets bored' (the electronic circuits that mediate this characteristic are the adaptive threshold devices and the mechanism involving the $\lambda(y_i) + \theta(y_i)$). In the absence of any input the system becomes increasingly sensitive and responds to any slight sound (while strictly desirable, this feature proved to be a nuisance in practice and it was suppressed by an arbitrary gain control circuit which limited the input amplifier gain in the absence of a sensible level of sound). Again, given a repetitive input, the system 'directs its attention' to the potentially novel.

However, the machine is eminently trainable and it is trainable in many different ways. The performer can use several gambits (all involving the accentuation of properties of the music) to reinforce the audio visual correlations which he prefers. At the lowest level, he can concentrate upon single properties of the music (and their visual correlates). At a higher level of interaction, he can make use of emphasis and accentuation in order to reinforce relations between groups of musical properties,[2] and the visual output. Later, I shall argue that he not only can do so but, in fact, does so.

The 'learning' mechanism, in particular its strategy, was chosen as one of many alternatives which foster the transfer of information around the entire feedback loop of figure 26, i.e. the loop involving visual display, performer, musical instrument and 'learning' machine. Phrased differently, the machine is designed to entrain the performer and to couple him into the system. In these terms, the importance of 'habituation' and 'novelty seeking' are evident if we also accept the proposition that man (the converse participant) is impelled to seek, learn about and resolve novelty in his environment.

In the display of figure 26, the $y_i$ specify the set of visual signs from which a selection is actually made. Several arrangements were used to satisfy this paradigm. One is shown in figure 27. The $x_i$ actuate five separate time-lagged dimmers which energize five projector spotlamps aimed at a cyclorama or screen. Each of these has a colour and pattern wheel, the object in figure 27, servo-positioned by the corresponding parameter switch (its position, $y_i$, determines which pat-

[2] The rhythmic property is inherently time dependent. Apart from this, the performer can establish time-dependent behaviour patterns in the system because of the form of search strategy.

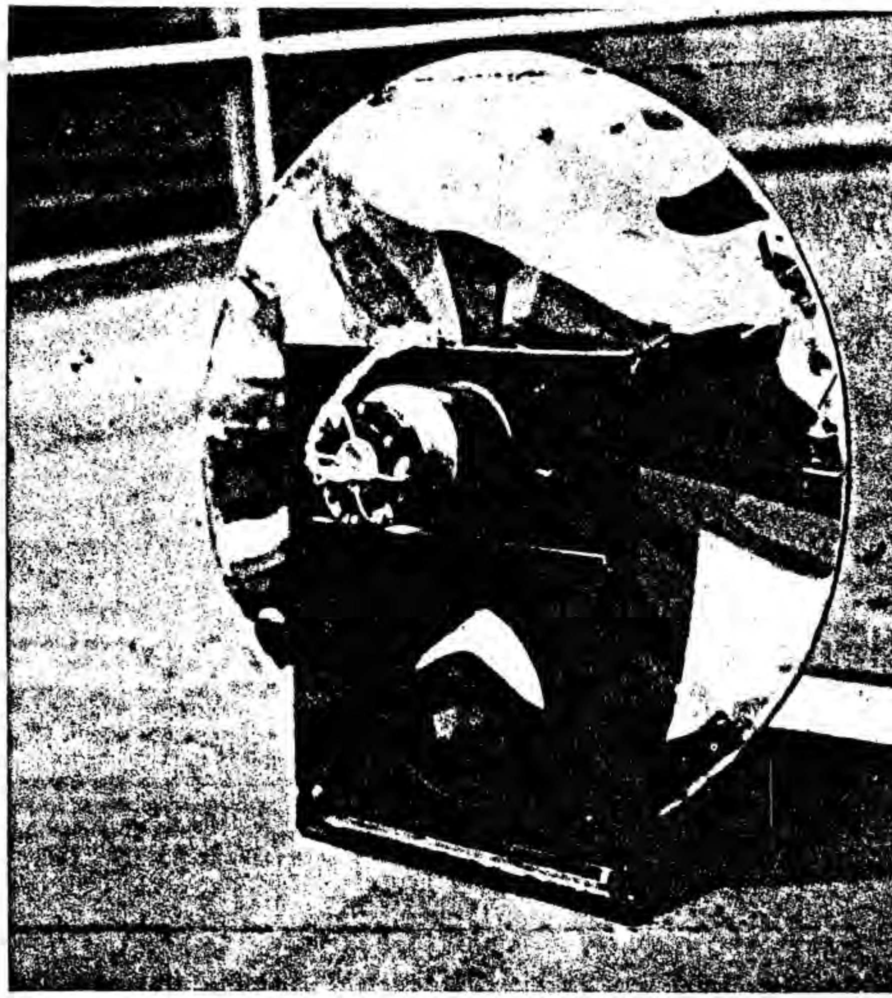


Fig. 27 Servo-positioned projection wheel.

tern will be projected if the spotlamp is energized). The colour and pattern wheels can be replaced by reflectors (servo-positioned in step with the parameter switches); a display of this sort is shown in figure 28.[1] Finally, the controlled position of reflectors can be replaced by the controlled motion of reflectors or three-dimensional objects. Each display mode was used in the first theatrical presentation of Musicolour which took place at the Boltons Theatre in 1955; figure 29 is a view of some details of the set.

[1] This account is somewhat over-simplified. In addition, the $y_i$ selected groups of lamps energized by the $x_i$. Typically, there were some fifteen different 1-kW lamps and fifteen different $\frac{1}{2}$-kW lamps usually arranged in three or four groups.

The Boltons show came about because some friends, who had seen the Musicolour system in Llandudno, ran a puppet theatre. We decided to combine marionettes with Musicolour in a piece entitled 'Moon Music'. But marionettes and Musicolour proved to be unhappy bedfellows. There were many difficulties. A number of mechanical creatures had been introduced, by way of gimmickry, one was humanoid, the others more freely conceived. These were meant to move in synchrony with the system output and, at

A

B

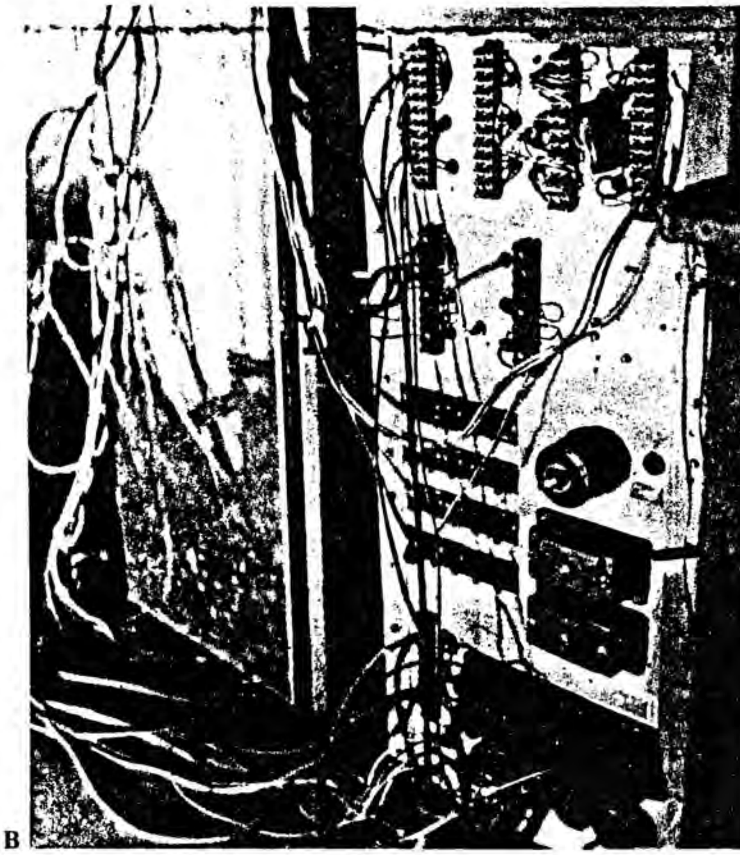


Fig. 28 Musicolour machine A, power boxes B, and reflector display C.

C

Fig. 29 Part of the Musicolour display at the Boltons Theatre.

rehearsals, they did so. On the first night, however, the humanoid dismembered himself (due to a malfunctioning feedback loop) and scattered his limbs among the audience. Another animal lost its front end. The marionette strings got helpelessly mingled with the display of figure 29. The audience was, at the most, bemused by the entertainment. Finally, our stage manager (who said he was used to puppets) went positively beserk after a week of it and sailed for Portugal. 'Moon Music' closed, leaving us with a month's paid-up rental on the theatre.

It would have been disastrous apart from Jone Parry, our musical director. But the spare month provided her with a public workshop in which to develop the musical potentialities of the system. The show reopened as a concert performance, with Jone, a flautist and a dancer, other musicians playing if they wished to. Jone worked out what a musician can do with the system, both as an aid to composition and an aid to performance. It turns out that one can do quite a lot, for a close co-operative rapport is soon established between the man and the machine.

On a technical level, it was possible to investigate the stability of the coupling, or rapport, which Jone rationalized in aesthetic terms. In this study arbitrary disturbances were introduced into the feedback loop without the performer's knowledge. Even though he is ignorant of their occurrence, these disturbances are peculiarly distracting to the performer, who eventually becomes infuriated and opts out of the situation. But there is an inherent stability in the man–machine relation which allows the performer to tolerate a certain level of disturbance. We found that the tolerable level increases as the rapport is established (up to a limit of one hour at any rate).

Fig. 30 Part of the Musicolour display at Valerie Hovenden's Theatre Club.

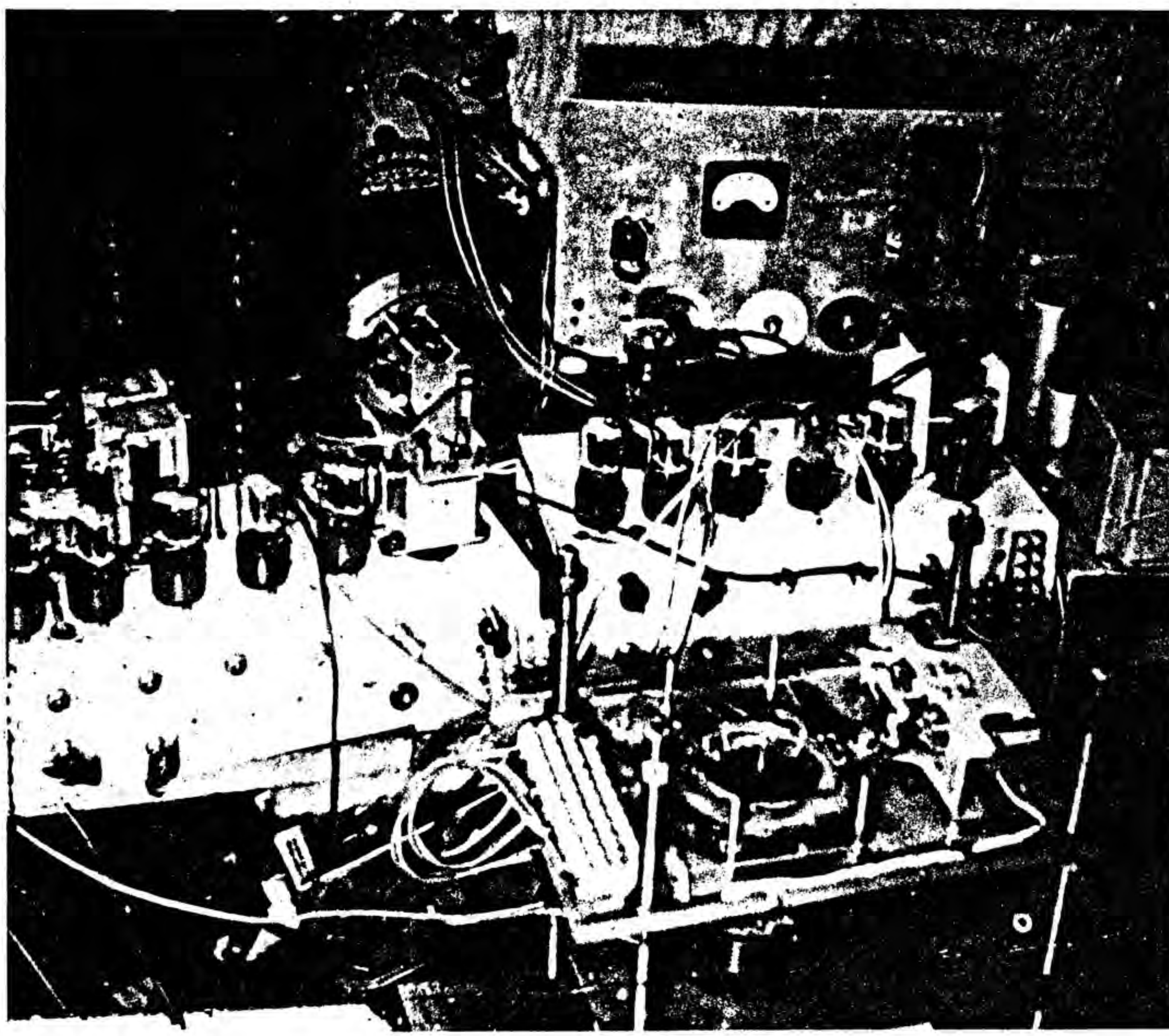


Fig. 31 Electrochemical system.

Meanwhile, John Clark, a psychiatrist, had come to the theatre and we jointly observed some phenomena related to the establishment of rapport. First, there is a loss of time sense on the performer's part. One performer, for example, tootled away on his instrument from 10 p.m. to 5 a.m. and seemed unaware that much time had passed; an hour, he thought, at the most. This effect (manifest to a much lesser degree) was ubiquitous. Next, there is a group of phenomena bearing on the way in which performers train the learning machine.

As a rule, the performer starts off with simple tricks which are entirely open to description. He says, for example, that he is accenting a chord in a particular passage in order to associate a figure in the display with high notes (he can either describe the figure or point it out when it occurs). Soon, and usually about the moment when a performer feels he has control of the system, the determinate trick gives way to a behaviour pattern which the performer cannot describe but which he adopts to achieve a well-defined goal. Later still, the man–machine interaction takes place at a higher level of abstraction. Goals are no longer tied to properties as sensed by the property filters (though, presumably, they are tied to patterns of properties). From the performer's point of view, training becomes a matter of persuading the machine to adopt a visual style which fits the mood of his performance. At this stage in the development of rapport, the performer conceives the machine as an extension of himself, rather than as a detached or disassociated entity.

You need a mellow, elegant, South Kensington period in developing any cybernetic art form.

The next public presentation of Musicolour was at Valerie Hovenden's Theatre Club in Shaftesbury Avenue; literally in the crypt of St Anne's. Miss Hovenden had encouraged me to write a review, 'Nocturne', with the system as a prominent feature. Some rather elaborate display mechanisms were used (see fig. 30) and 'Nocturne', as a whole, was moderately successful. The chief cybernetic developments were an attempt to link the motions of a dancer to the input of the machine (this proved technically difficult but the aesthetic possibilities are indisputable), and a rough and ready study of the perceptual properties of the system. Cogent visual symbols appear to act as 'releaser' stimuli and observations of Clark and myself suggested that the most effective 'releasers' are short sequences of visual events, rather than static configurations.

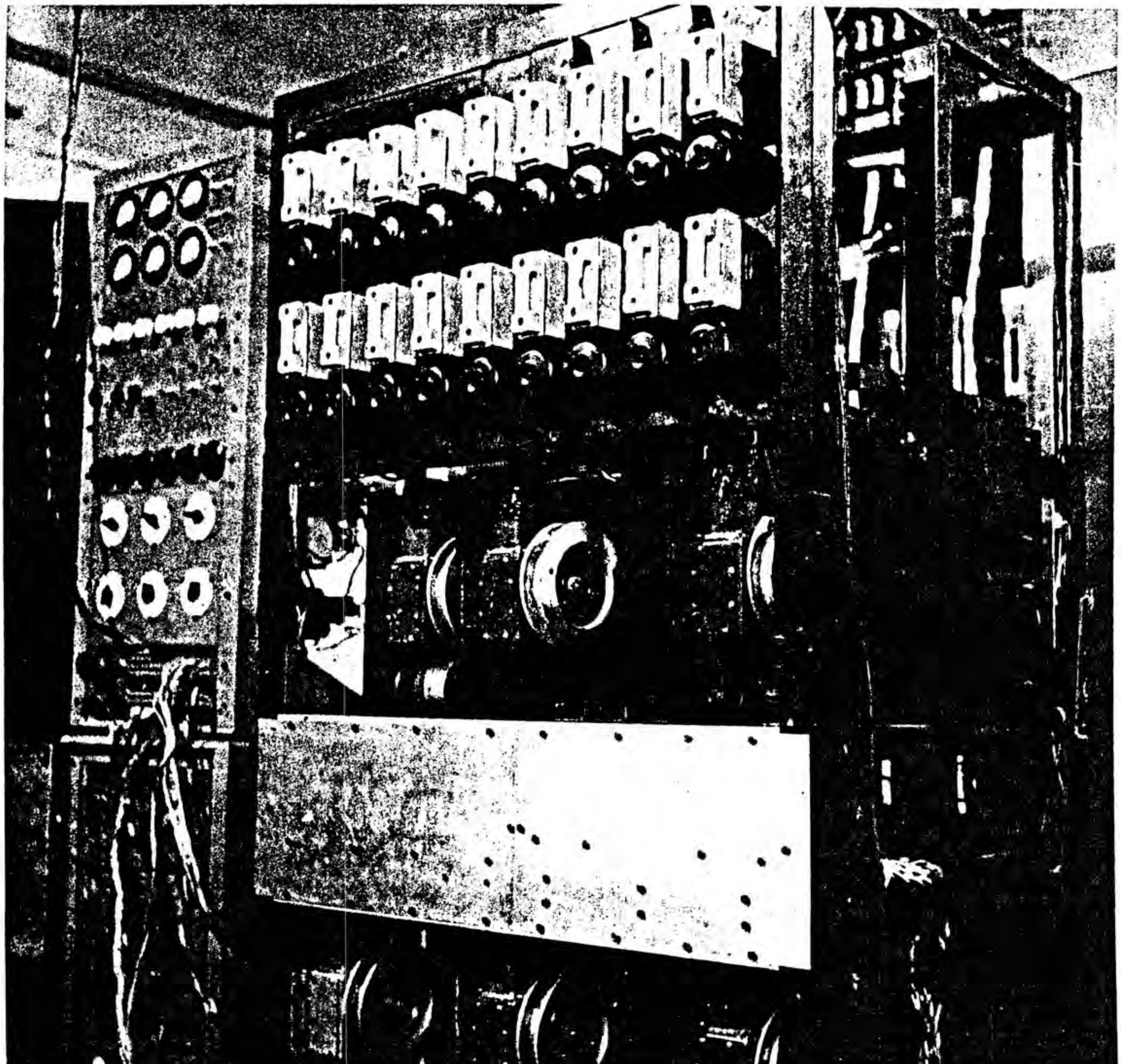
Since the system was costly to maintain and since the returns were modest, the Musicolour enterprise fell into debt. We secured inexpensive premises above the Kings Arms in Tabernacle Street which is a curiously dingy part of the city of London, often engulfed in a sort of beer-sodden mist. There, we set up the system and tried to sell it in any possible way; at one extreme as a pure art form, at the other as an attachment for juke boxes.

The only real development during this period was an electro-chemical display. It consists of several shallow dishes, one for each output variable, mounted on rotatable frames (one dish is shown in fig. 31). Each dish contains electrolyte and an indicator (which changes colour when the pH of the solution is altered, for example, by local electrolysis). The output $x_i$ energizes electrodes positioned in the $i$th dish. Current passes, local electrolysis occurs and a colour pattern is built up. The output $y_i$ rotates the $i$th dish with respect to the electrodes. The patterns are projected on to a screen.

Fig. 32 Musicolour display at Churchill's Club.

At this moment, fortune changed a bit, though from a cybernetic point of view the story is nearly told. Cecil Landau became a partner in the enterprise and presented Musicolour in his revue at Churchill's Club (fig. 32). The show was presented twice nightly, at 11 p.m. and 1 a.m. and it had the glittering theatrical proportions to which Mr Landau was accustomed. Indeed, he was prone to regard an

Fig. 33 Musicolour was equipped with a servo-dimmer board and transferred to the Mecca Locarno at Streatham.



archway across the middle of the night-club as a surrogate proscenium and everything beyond it as a stage. But this view of the world was not generally accepted and, in practice, the Musicolour installation sat in a service passage. There it had to be guarded from the half fearful attention of dance hostesses and from waiters who adopted a cavalier attitude to the instrument and dropped cutlery into its entrails. For all that, the audience reaction was favourable and Musicolour became a permanent feature of the spectacle.

We also used the system when people were dancing and discovered that in these conditions an audience can participate in the performer–machine feedback loop just because they are doing something to music and the band is responding to them.

The following year, the system was equipped with a servo-dimmer board (fig. 33), and was transferred to the Mecca Locarno at Streatham. It was used to modulate about 120 kW of power in the existing lighting installation. With a good rhythm group it acted as a conductor, that is, it pulled the group into more fully co-operative activity. With a large band it was less effective. In any case it induced very little participant activity on the part of the dancers in this large dance-hall. We learned that in order to obtain any participation at all, it is necessary to exclude spatial cues that allow the audience to opt out of the display environment. Even an illuminated Exit sign is a nuisance in this respect. On the whole, however, the dancers (in contrast to the band) regarded Musicolour as another fancy lighting effect. It was clear that in large scale (and commercially viable) situations, it was difficult or impossible to make genuine use of the system.

Musicolour made its last appearance in 1957, at a ball organized by Michael Gillis. We used a big machine, a small machine and a collection of display media accumulated over the years. But there were other things to do. After the ball, in the crisp, but fragrant air of St James's Park, the Musicolour idea was formally shelved. I still have a small machine. But it does not work any longer and is of chiefly sentimental value.

**A plan for an aesthetically potent social environment**

The 'colloquy of mobiles' presented at the Cybernetic Serendipity exhibition is completely system-designed and its electronic parts are largely detailed. It is a socially orientated reactive and adaptive environment. Even in the absence of a human being, entities in the environment communicate with and learn about one another. But a human being can enter the environment and participate; possibly modifying the mode of communication as a result.

To begin with it was necessary to select a structural idiom; preferably (to avoid undue strangeness) an idiom that is accepted within the conventions of art. Rather arbitrarily, I chose to make the communicating entities mobiles and the environment into a community of mobiles. These, however, are powered mobiles, the motion of which is partially determined by instructions from a program (though there are haphazard components as well). They are also provided with computing systems to control their activity.

Next, it was necessary to equip the mobiles with a language in terms of which they can communicate. As a compromise between cogent visual effect and technical convenience, I chose an alphabet of visual signs and audible signs. Each mobile is able to emit and recognize several different colours and time modulations of light and several different tones and time modulations of sound. The syntax of the language depends upon interpretation rules built into each mobile (we come to these in a moment). But, as it stands, the language is no more than a code. Communication could be made to occur but only in the trivial sense of an epiphenomenon. To give meaning to the communication, the mobiles must be given a reason for talking to one another and a set of goals to aim for.

Scrutiny of the goal problem reveals the following desiderata (which may also be regarded as, in some sense, prerequisites for a meaningful community of mobiles which has a chance of being an aesthetically potent environment):

1 The goals of the several mobiles should be partially incompatible, so that the mobiles compete with one another.
2 Some of the goals should be incapable of attainment by any one mobile on its own. In order to achieve such a goal, at least a pair of mobiles must co-operate and in order to co-operate, they must communicate with one another.

3 The main goals of a mobile should be decomposable into sub-goals so that any mobile contains an hierarchical organization.
4 Co-operative interaction must involve main goals and sub-goals so that there are several levels of communication in the system.
5 The pursuit of the lowest level sub-goals should be carried out by autonomously acting programs embedded in each mobile. Whereas selection of these programs depends upon communication mediated feedback, their execution does not. This is one way (incidentally, a biologically important way) of decoupling the mobiles and maintaining their individual integrity.

As designed, there are two sorts of mobiles in the population; say 'male' and 'female'. They are arranged as shown on the plan of figure 34*a* and the elevation of figure 34*b* (this is probably the simplest arrangement; other configurations are possible and the size of the community can be enlarged without seriously affecting the design). The male mobile has two 'drives', *O* and *P* (associated with orange- and puce-coloured light) and its drive state is indicated visually by an upper display, *A*. Its main goal is to satisfy (or reduce) the *O* and *P* 'drives' which normally build up over time. It can do so, in the case of *O*, by projecting an intense beam of orange light from its central part, *B*, in such a way that it falls upon receptors in its upper part, *C*; in the case of *P* satisfaction it must project an intense beam of puce light from *B* in such a way that it falls on receptors in the lower part, *D*.[1] In order to achieve this goal it must elicit the co-operation of a female who, unlike the male, is provided with a vertically positionable reflector capable of taking the beam from *B* and reflecting it back either to *D* or *C*.

First, of course, it must find a female. To do so, the male engages in motions that:

1 Rotate the bar linkage, *Z* and
2 Rotate each male about its point of suspension.

So far as the first motion is concerned, a sort of 'territorial' competition may take place between male I and male II, if their search instructions are in conflict, for example, if I has found a female and wants to remain stationary, but II wants to continue searching. The conflict is resolved[2] by an aggression display (in which the relative power of the males depends upon their drive states). So far as the second motion is concerned, the males are independent (though there is still a sense in which they compete for the available females).

Consider a particular state[3] of any one male, for example, the state in which male I has drive *O* greater than drive *P* and has not found a female to help it. In this case, male I sends out an intermittent directional visual signal which serves to identify it as 'male I' and its desire as '*O* satisfaction'. It moves according to (1) and (2) above (unless (1) is blocked by male II) seeking a co-operative and receptive female (the females are normally in rotational motion, seeking males). Should the directional signal fall on the receptor *a* of a female who is willing to co-operate, she produces an identifying sound in synchrony with the intermittent light signal. Male I detects the correlation between the female and his light signal and stops his motion (unless he is prevented from doing so by male II). At this point, he triggers off an autonomous energetic event which consists in shining an intense orange light, for at least a minimum interval, in the direction of the located female. The immediate result is an increase in the *O* drive. However, male I anticipates subsequent reinforcement (which he will achieve if the female behaves appropriately and if the free moving part, *C*, is appropriately positioned during at least some of this behaviour). Reinforcement, which substantially *reduces* the *O* drive, is obtained if the *O* goal is satisfied; that is, if orange light falls on the receptor in *C*. Supposing reinforcement occurs, male I emits an identifying sound signal which is received by the co-operating female; the autonomous energetic event is prolonged and the *O* drive is decreased.

The co-operative encounter terminates after a short time if reinforcement does not occur, or if it is externally disrupted. Otherwise, it continues until the drive state of male I is modified so that he aims for a different goal.

[1] *D* and *C* are free-moving members loosely coupled to the main mobile body.

[2] I shall not go into the aspect of the system, for its details are not yet worked out.

[3] The relevant states are 'upper limit $\gg$ drive $O >$ drive $P \gg$ lower limit', which induces an *O* satisfaction search; 'upper limit $\gg$ drive $P >$ drive $O \gg$ lower limit' which gives rise to the converse; 'lower limit $>$ drive $O$ *and* lower limit $>$ drive $P$' in which case the male is satisfied and indifferent, and 'drive $O >$ upper limit *and* drive $P >$ upper limit' which produces a search for either *O* or *P* satisfaction.

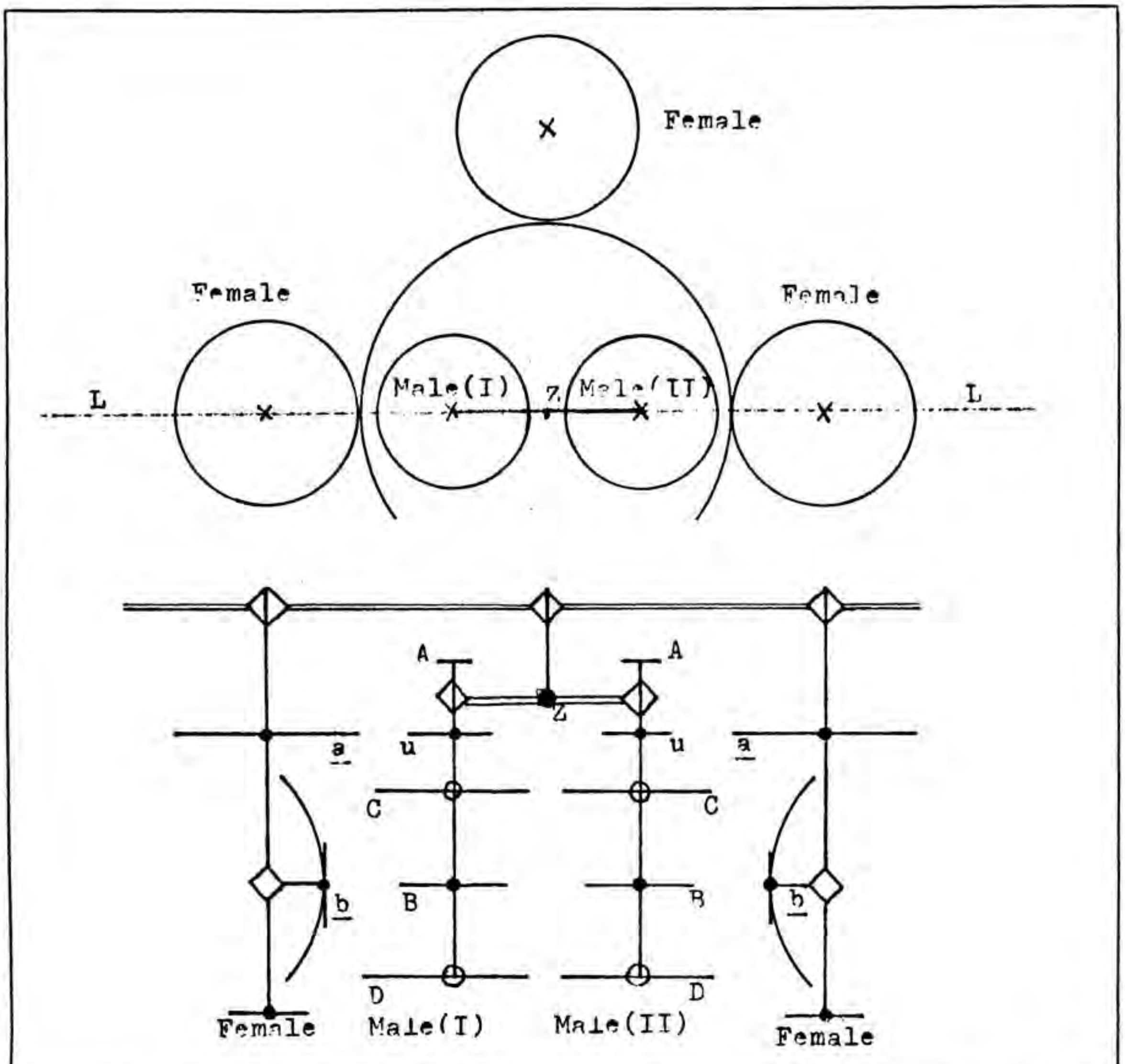



Fig. 34 A rough sketch of powered mobiles.

**a** Horizontal plan

**b** Vertical section taken through line $L$ in horizontal plan.

$A$ = drive state display for male

$B$ = main body of male, bearing 'energetic' light projectors $O$ and $P$

$C$ = upper 'energetic' receptors

$D$ = lower 'energetic' receptors

$U$ = non-'energetic', intermittent signal lamp

$a$ = female receptor for intermittent positional signal

$b$ = vertically movable reflector of female

$Z$ = bar linkage bearing male I and male II

= Drive motor

= Free coupling

= Fixed coupling

= Bar linkage

It is evident that the achievement of the *O* satisfaction goal involves an hierarchy of sub-goals and that communication in pursuit of these sub-goals takes place at various levels. Further, the selection of a main goal (such as *O* satisfaction) involves a still higher level process. Referring back to the list of desiderata, we can check that the male members of the mobile community satisfy all of them.

Consider a female: she also has an *O* drive and a *P* drive. Unless both drives are satisfied (when she becomes inert) the female rotates and searches for a male. According to her drive state, she is receptive to males offering *O* or *P* co-operation or to both. Suppose that she is looking for *O* co-operation and suppose she encountered male I in the state already described, on receipt of his intermittent directional signal, she puts his name 'male I' and his intention '*O* satisfaction' into a short-term memory. Next, she emits the correlated sound which he can recognize and expects to receive the 'energetic' beam of orange light. If this *does* fall on her vertical reflector, *b*, she stops her rotational motion and starts a search, using this reflector, to position the beam on some part of male I that will give rise to a reinforcement signal; her goal is to obtain the conjunction of orange light on her reflector and the reinforcement signal from male I; goal achievement reduces her *O* drive. Her likelihood of achieving this goal in the rather short time allowed for an unreinforced encounter, depends upon the vertical reflector search strategy and this in turn depends upon her previous experience (upon what she has learned and placed in a long-term 'memory'). In ignorance of males, her vertical strategy is a haphazard search reflecting the beam up and down. However, if she has previously learned that reinforcement for *O* light comes from reflecting it upwards (in fact on to *C* of male I), then her strategy becomes a limited upwards search. A similar comment applies to *P* experience. Further, not all males are necessarily the same; some may like *O* light on *D* and *P* light on *C*; she can learn that trick also.

In any case, the vertical search strategy terminates after a short time (and the rotational search is resumed) if a reinforcement signal is not received from the male.[1] If a signal is received, the vertical search is prolonged possibly until the female drive state has been modified. The whole process is summarized in the accompanying flow-charts. There are five independent systems, three female and two male which are run asynchronously in parallel. The flow-charts of figures 35, 36 and 37 represent a female system and the flow-charts of figures 38 and 39 represent a male system.

This completes[2] our description of the social environment of mobiles.

The really interesting issue is what happens if some human beings are provided with the wherewithal to produce signs in the mobile language and are introduced into the environment. It is quite likely that they will communicate with the mobiles, for the mobiles are interacting already and ostensively define the gambits involved in the process. Further, their community has quite an intriguing organization. At this level alone. the environment has the properties required of an aesthetically potent environment.

But the mobiles produce a complex auditory and visual effect by dint of their interaction. They cannot, of course, interpret these light and sound patterns. But human beings can and it seems reasonable to suppose that they will also aim to achieve patterns that they deem pleasing by interacting with the system at a higher level of discourse.

I do not know. But I believe it may work out that way.

[1] The vertical search is the female form of an autonomous process.

[2] We have cited special cases. The account is, however, readily generalized to cover all initial conditions of the mobiles.

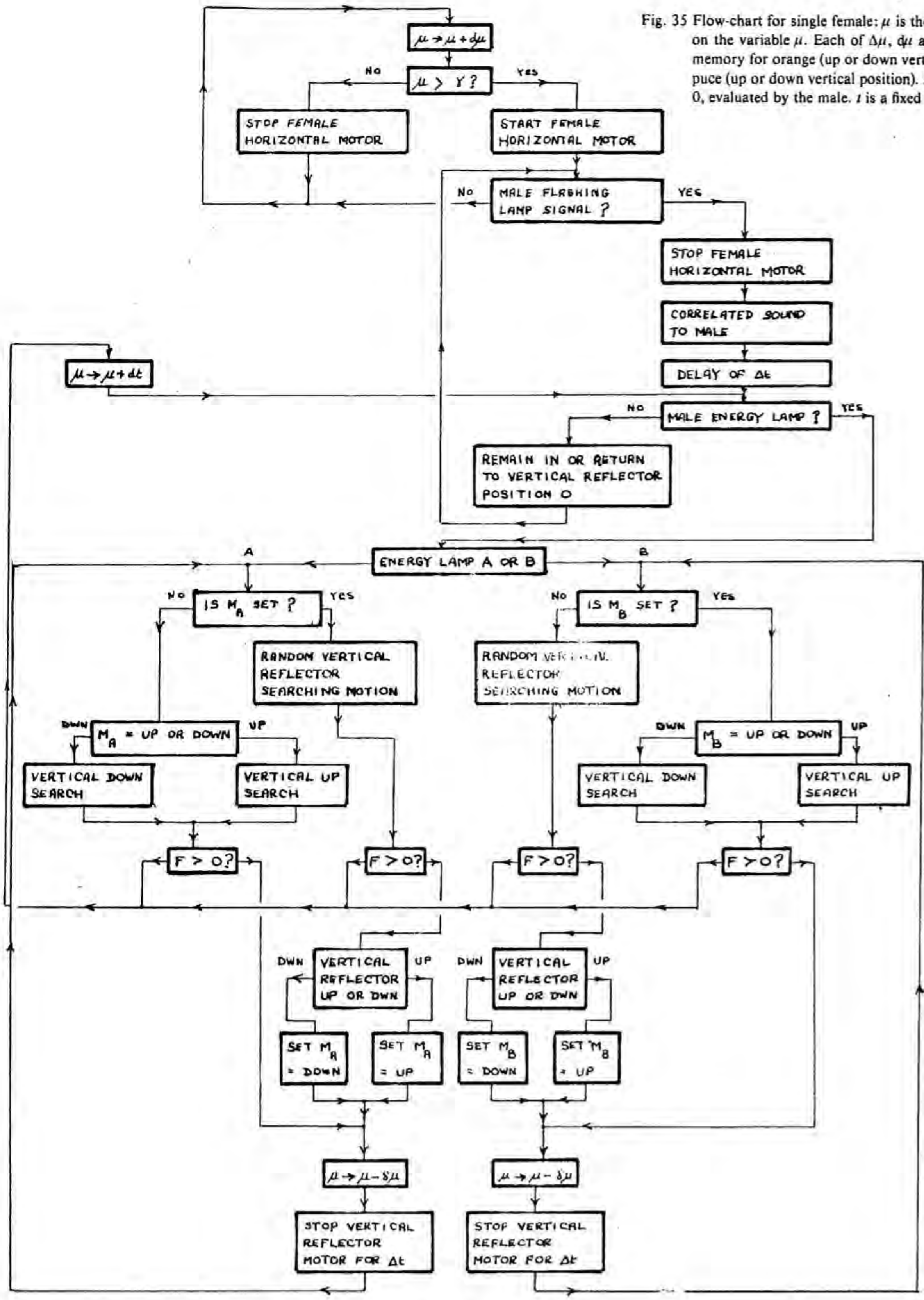
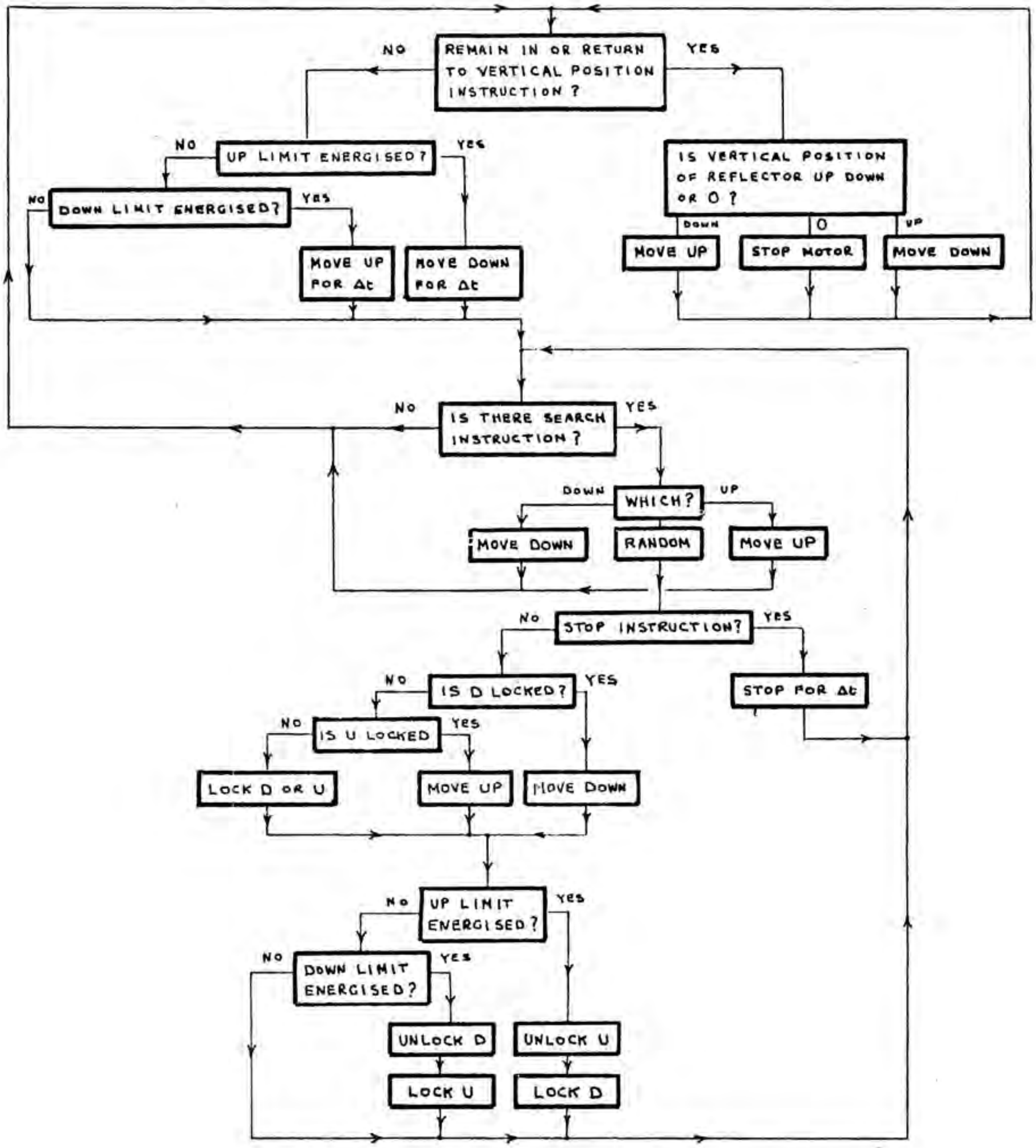



Fig. 35 Flow-chart for single female: $\mu$ is the female drive variable and $\gamma$ is a limit on the variable $\mu$. Each of $\Delta\mu$, $d\mu$ and $\delta\mu$ is a different increment. $M_A$ is memory for orange (up or down vertical position) and $M_B$ is a memory for puce (up or down vertical position). $F$ is a reinforcement variable, $F = 1$ or 0, evaluated by the male. $t$ is a fixed delay.



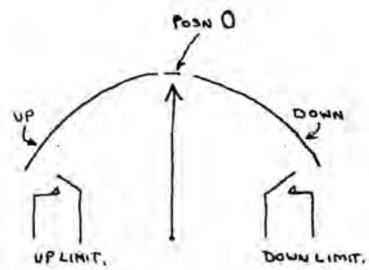




Fig. 36 Female vertical reflector sub-system. Flow-chart for control of vertical motors. This sub-system receives instructions from the main female program, information from a pair of limit switches, and a positional sensing switch on the vertical reflector motor. *D* and *U* are lock relays.

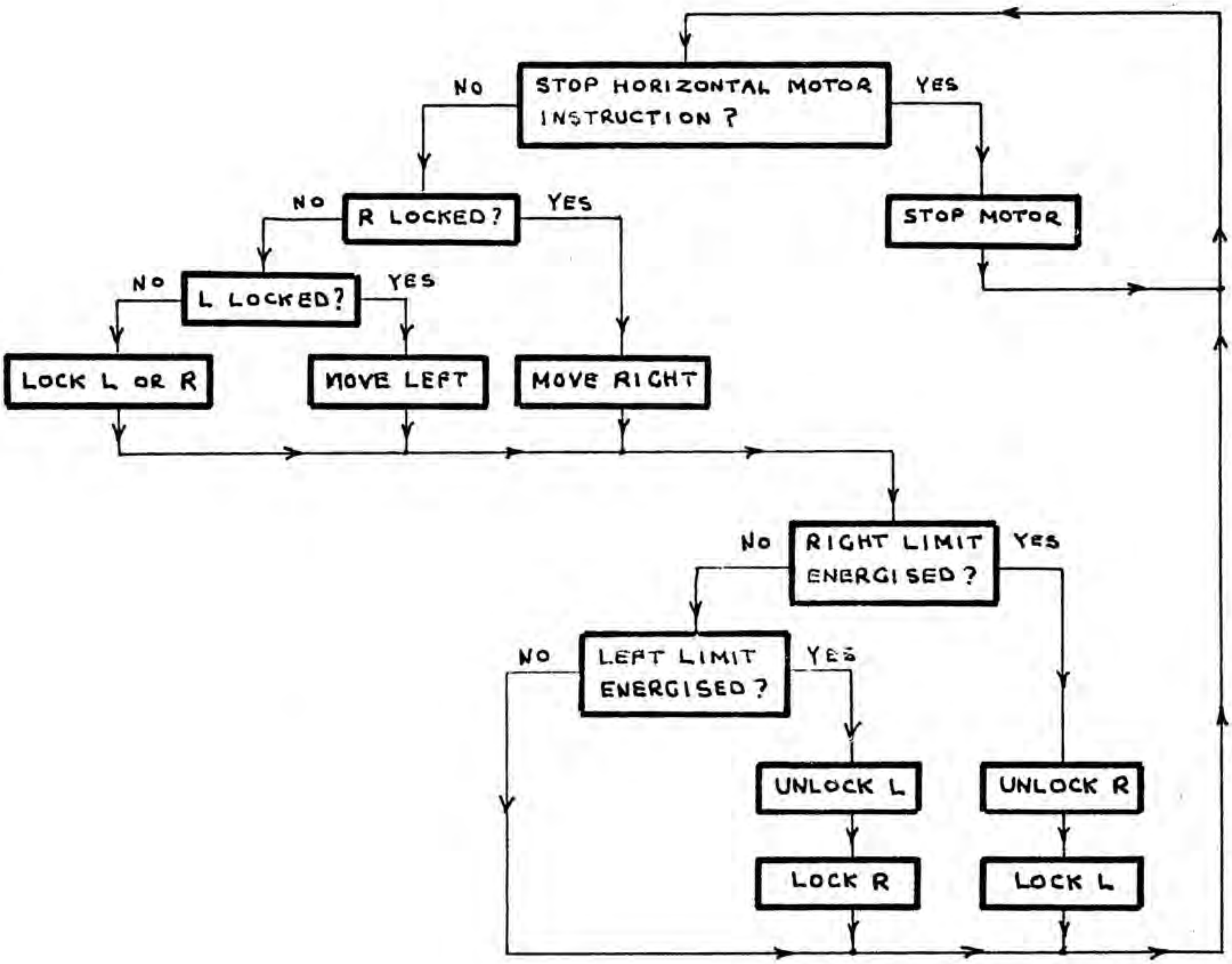



Fig. 37 Flow-chart for female horizontal control sub-system. This sub-system receives horizontal stop instructions from the main female sub-system, information from right and left limit signals. *R* and *L* are lock relays.

*opposite*

Fig. 38 Flow-chart for male: $A$ = orange memory lamp; $B$ = puce energy lamp. Flashing signal is male–female communication signal.

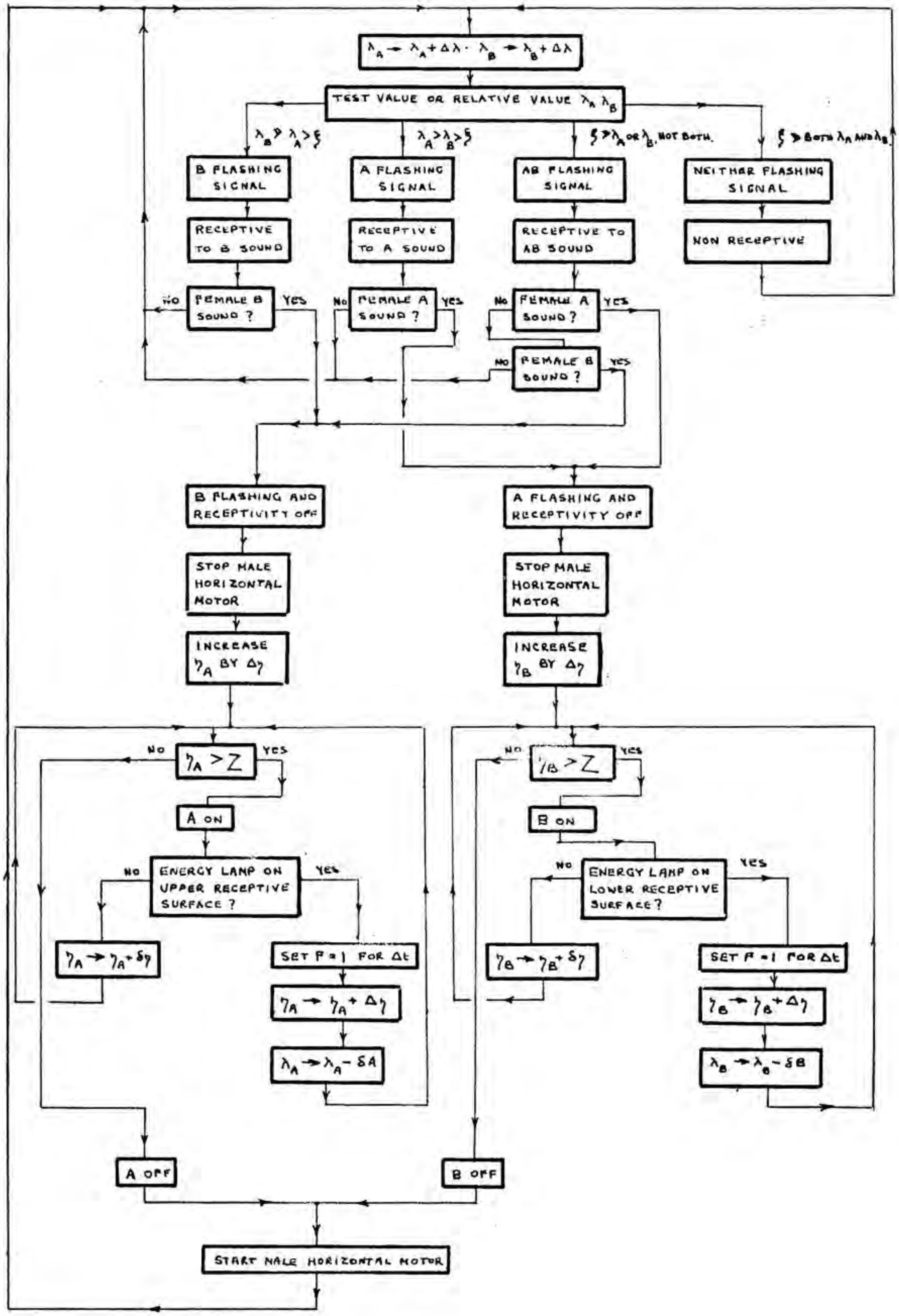
$\lambda_A$ $\lambda_B$ are the male drive variables.

$\eta_A$ $\eta_B$ are the male internal state variables.

$\xi$ is a limit on $\lambda$ and Z is a limit on $\eta$.

It is assumed that this male is reinforced if either the *A* male energy lamp is reflected on to its upper receptive surface or if the *B* male energy lamp is reflected on to its lower receptive surface.

*F* is a reinforcement variable, $F = 1$ or 0, the value of which is also conveyed to the female.


λA → λA + Δλ · λB → λB + Δλ
TEST VALUE OR RELATIVE VALUE λA λB
λB > λA > ξ
λA > λB > ξ
ξ > λA OR λB, NOT BOTH.
ξ > BOTH λA AND λB.
B FLASHING SIGNAL
A FLASHING SIGNAL
AB FLASHING SIGNAL
NEITHER FLASHING SIGNAL
RECEPTIVE TO B SOUND
RECEPTIVE TO A SOUND
RECEPTIVE TO AB SOUND
NON RECEPTIVE
NO
FEMALE B SOUND ?
YES
NO
FEMALE A SOUND ?
YES
NO
FEMALE A SOUND ?
YES
NO
FEMALE B SOUND ?
YES
B FLASHING AND RECEPTIVITY OFF
A FLASHING AND RECEPTIVITY OFF
STOP MALE HORIZONTAL MOTOR
STOP MALE HORIZONTAL MOTOR
INCREASE ηA BY Δη
INCREASE ηB BY Δη
NO
ηA > Z
YES
NO
ηB > Z
YES
A ON
B ON
NO
ENERGY LAMP ON UPPER RECEPTIVE SURFACE ?
YES
NO
ENERGY LAMP ON LOWER RECEPTIVE SURFACE?
YES
ηA → ηA + δη
SET F = 1 FOR Δt
ηB → ηB + δη
SET F = 1 FOR Δt
ηA → ηA + Δη
ηB → ηB + Δη
λA → λA − δA
λB → λB − δB
A OFF
B OFF
START MALE HORIZONTAL MOTOR

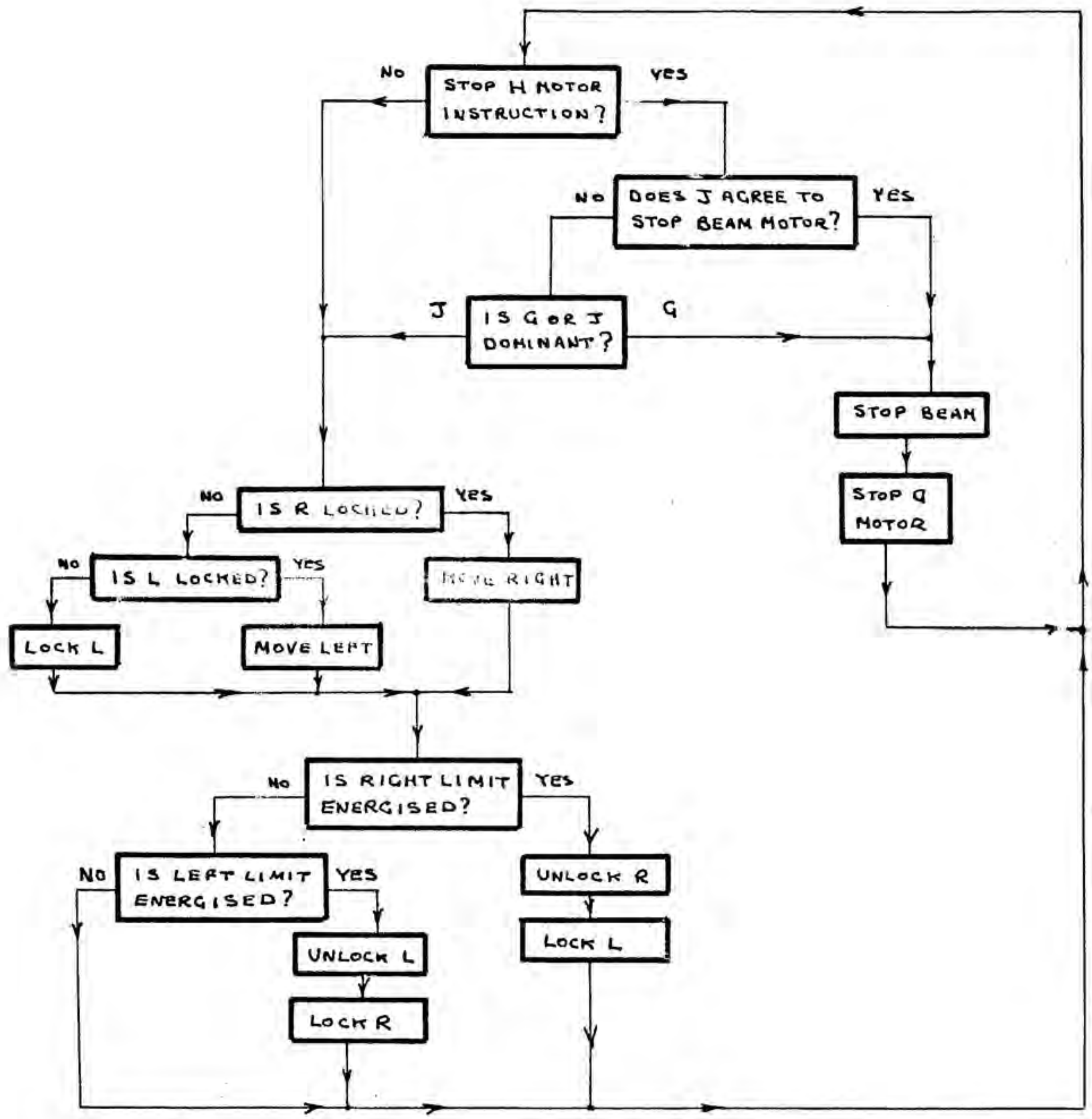



Fig. 39 Male horizontal sub-system: The male horizontal motor (H motor) for each male receives left and right limit signals. There are two males, G and J, this flow-chart is for G only. G and J are mounted on a common beam driven by a beam motor. The normal state for the *H* motor of G, or J, and the beam motor is to be in motion. Thus they are stopped only when a stop instruction is effective. The beam motor, which obeys a similar flow-chart, is normally in quasi random motion scanning its entire track.

*opposite*
Fig. 40 A view of the 'colloquy of mobiles'.

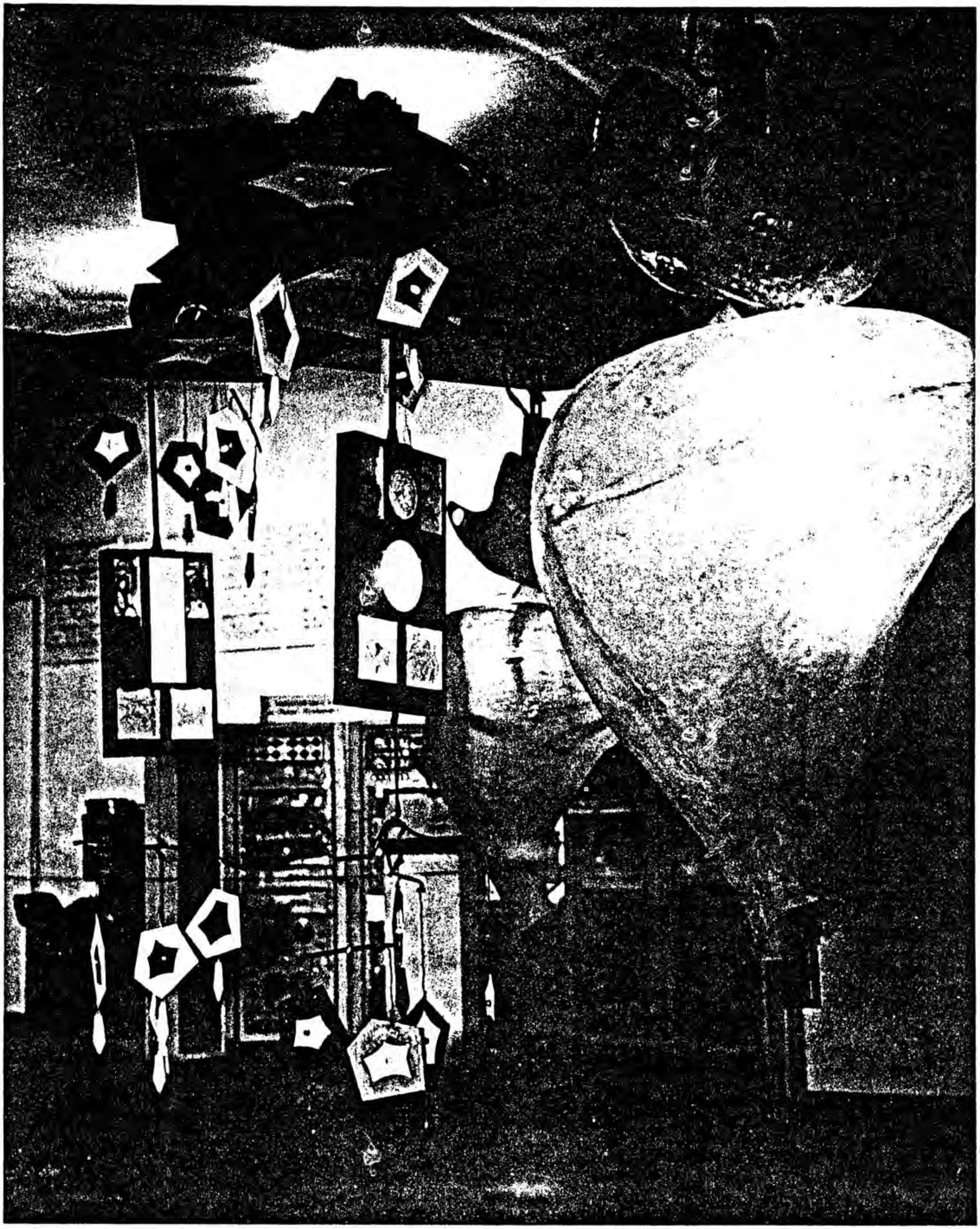


Fig. 41 Close-up of female showing reflector mechanism.

**Appendix** (added in October 1968)
Since this article was written, the plan for the colloquy of mobiles has been realized (Cybernetic Serendipity, ICA, London, 1968). The real system followed the plan quite closely (only the 'energy lamp' controls being replaced by a somewhat simpler arrangement and the territorial circuit controlling the male beam by a majority decision device). Hence the flow-charts (figs. 35 to 39) are substantially unaltered. Figure 40 is an overall view of the colloquy with its special purpose computer in the right background; here the signalling equipment and the sensory 'vanes' of the male are clearly visible. The light splodges above the males (hanging on the central beam) symbolize their drive levels. Figure 41 is a close-up shot showing a female trying to satisfy a male by adjusting her servo-driven reflector to direct his energy light back to his sensory vanes; her drive level is symbolized by her body illumination. Figures 42 and 43 show the mobiles interacting in the dark. Under these circumstances the prediction contained in the last paragraph of the paper is quite accurate, though entrainment is not nearly so effective with even moderate ambient illumination level. The 'female' forms were designed by Yolanda Sonnabend, the inner 'male' forms and the general set-up by myself; Mark Dowson constructed the electronics and Tony Watts was responsible for the electromechanical side of the project.

*opposite*
Fig. 42 Mobiles interacting in the dark (shot 1).
Fig. 43 Mobiles interacting in the dark (shot 2).

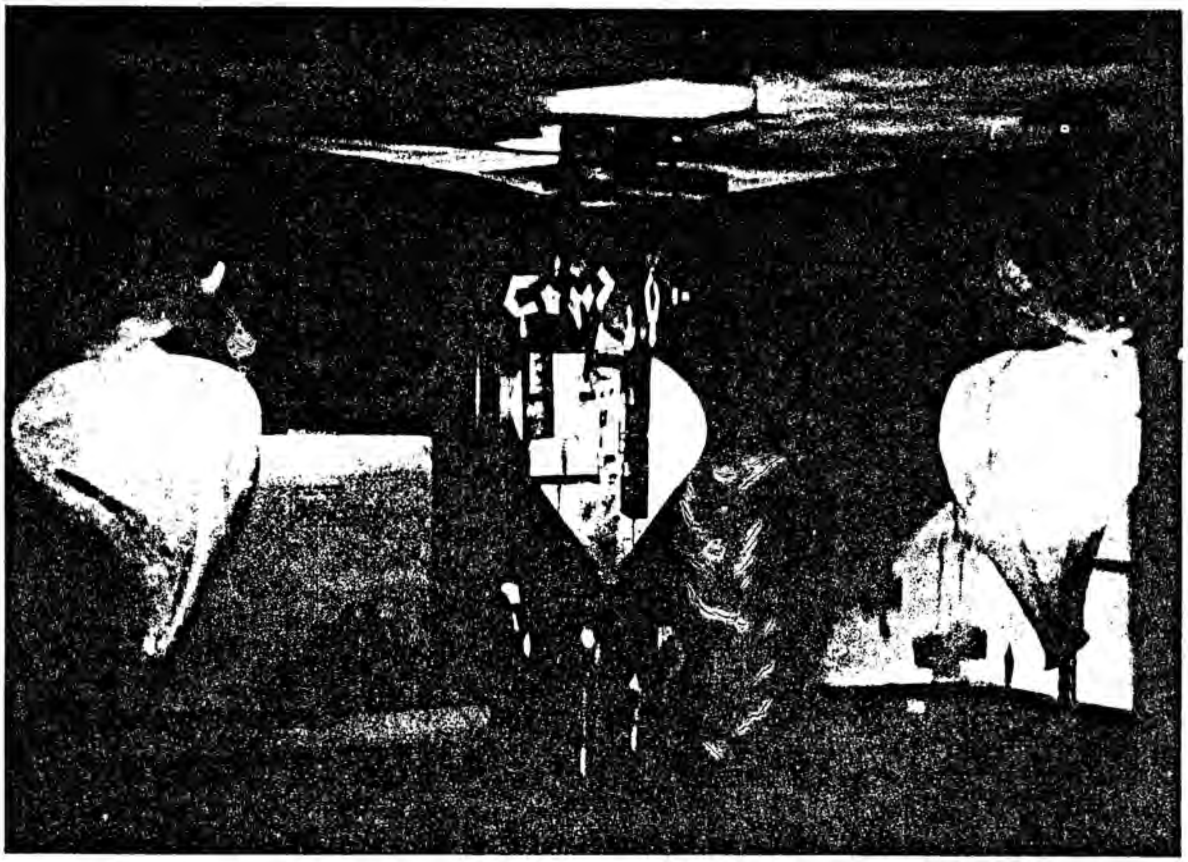


Fig. 42

Fig. 43