SPEECH AND THE REGULATION OF BEHAVIOUR

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SUMMARY

This thesis presents an examination of a theory about
the function of language.   The theory, proposed by
L.S. Vygotsky and elaborated by A.R. Luria, is that
language, in the form of self-instructions, plays a
crucial role in the organisation of behaviour.   For
Vygotsky self-instructions help to set the goals of
behaviour;   Luria adds the claim that they also enter
into the very organisation of the ongoing motor
responses whereby those goals are achieved.   These
processes are held to be particularly important and
prominent in young children.

Two levels of generality can be discerned in
Luria's theory.   On one level he proposes specific
models (which are here dubbed the Feedback and Shunt
models respectively) which account for certain features
of the verbal regulation of behaviour.   The first pair
of experiments are designed to test two important
assumptions of these models, namely that in young
children the motor system suffers from a lack of proprio-
ceptive feedback, and that the verbal system is in
certain specific respects more highly developed than the
motor system.   Strong doubt is cast on these claims and
alternative explanations are proposed for the observed
results.

The investigation then passes on to a more general
formulation of Luria's theory and searches for evidence

of verbal components in the organisation of motor responses. Some Skinnerian work allegedly providing this is reviewed and criticised; its shortcomings are used to suggest the focus of the next two experiments. These establish that self-instructions, whether overt or covert, can actively interfere with the conduct of a simple motor task like tapping. It is found, though, that the relative load of covert commands is less than that of covert countermands in 6 year olds. This may be an example of verbal self-regulation, though other possible explanations are considered.

The central experiments of this study also examine the effect of placing overt self-instructions in opposition to a motor set in young children (age 6), but this time in more complicated tasks. Ss responded by uttering one of two colour names and by pressing one of two coloured buttons to the forced-paced, serial presentation of two coloured light signals. The independent variables were, (i) speed of presentation, (ii) S-R compatibility, and (iii) R-R compatibility. The regulatory theory predicts more interference with the motor task than the verbal task. No such overall effect is found. Although in some situations the motor system suffers more disorganisation than the verbal system, in others it is the verbal system which appears to be dominated by the motor system. The crucial variable is found to be S-R compatibility. The experimental result presents severe difficulties for the

regulatory theory and so an alternative theory is
proposed.   This is based on considerations of limited
channel capacity, and treats the verbal and motor
systems as otherwise independent.

This dissertation is the result of my independent work. The material has not been submitted for any other degree.

David Bloor

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE VYGOTSKY-LURIA THEORY OF VERBAL SELF-REGULATION

In his book Thought and Language the Soviet psychologist
L.S. Vygotsky (1962) proposed the idea that the role of
language in child development goes beyond that of
forming a bond of communication between adult and child.
It also, he argued, enters into the organisation of the
child's voluntary behaviour in the form of self-
generated, verbal instructions which in some sense
regulate the behaviour.

This chapter begins with a statement of Vygotsky's
basic ideas. The development of the theory by A.R.
Luria is then examined and some theoretical and
experimental objections are considered. Finally a
general formulation of Luria's theory is given which
provides the focus of subsequent experiments.

Vygotsky's Theory

For Vygotsky (and to some extent Luria) the
situation which functions as the basic model for self-
regulation by speech is quite simply that of behaviour
regulation by the speech of others. The regulation of
behaviour by speech might be defined by pointing to
cases of a parent manipulating the behaviour of a child
by speaking to it. Having defined what is meant by
'regulation' the move must then be made from 'other-

regulation' to 'self-regulation'.   Since a child
obviously has a verbal output as well as a motor output
it should be possible to conceive the child providing
his own source of instructions.   Luria (1961, p. 3)
explains Vygotsky's position by referring to a 'process
in which functions previously shared between two persons
gradually change into the complicated functional systems
in the mind which forms the essence of human higher
mental activity'.

Some remarks should perhaps be made about
Vygotsky's main theoretical move.   It consists in
trying to understand the workings of a single person by
viewing him as an amalgam of two persons.   It may be
argued that any theory based on such a move will be
empty because it is a case of illustrating idem per idem.
Clearly there are dangers here, but a simple defence can
be constructed by pointing out that many other theories
would perish if this objection to Vygotsky's move were
sound.   For example, Freud analyses the personality in
terms which ultimately must be seen as treating the
individual as an amalgam of a number of competing
individuals each with their own unitary but radically
different personalities.   Again, the charge of
emptiness of just the sort considered here used to be a
favourite argument against atomic theories in physics
and chemistry (e.g. Stallo, 1881).   The theory was said
to be devoid of content because it led to an infinite
regress.   In this last case the very success of atomic

theories permits the conclusion that however sound the criticisms may appear to be they cannot, when properly understood, really tell against the value of a theory. (For a full discussion of these issues see Bloor, 1970.) It therefore seems perfectly acceptable for a theorist to make precisely the sort of theoretical move that Vygotsky makes.

Given his basic position Vygotsky is able to identify those cases when a child is engaging in self-regulating speech. These are the occasions when the speech is what Piaget (1926) called 'egocentric'. Vygotsky, then, differs from Piaget in the interpretation to be given to the decline of egocentric speech which takes place at about the age of 7. For Vygotsky the decline represents the final internalisation of regulatory speech after its splitting off from social speech. For Piaget this decline is simply the atrophy of unsocialised speech. To support his case Vygotsky points to the changing structure and decreasing intelligibility of egocentric speech as its amount declines. Vygotsky's more direct evidence for the regulatory role of egocentric speech is limited to observations such as that the amount of egocentric speech increases with task difficulty and frustration. These observations are reinforced by anecdotal evidence. For example, it is noted that a young child drawing a car exclaimed "broken" when his crayon broke, and then proceeded to draw a broken car.

Vygotsky contrived an experiment (which he thought was a crucial experiment in Bacon's sense) to test his theory of egocentric speech against Piaget's. Briefly, Piaget's theory can be characterised by imagining the social world and the egocentric involvement of the child as two forces pulling in opposite directions. Limiting the 'social pull' by restricting the possibility and appropriateness of communication should increase the pull of the ego and so increase the amount of egocentric speech. Vygotsky's theory results in the opposite prediction. For Vygotsky the reason why speech-for-self occurs out loud at all is because the child cannot distinguish those situations calling for external speech and those calling for silent speech. Cutting down the possibility of communication should make the discrimination easier, so the amount of egocentric speech should go down. Placing children in a noisy environment or amongst deaf and dumb children reduced egocentric speech to almost zero, as Vygotsky predicted.

As Duhem pointed out long ago (Duhem, 1906) the idea of a crucial experiment is suspect because of the large number of background assumptions underlying any experiment. In this case it is evident what scope there is for alternative explanations of the reduction in egocentric speech in the situations described.

Recent experiments, however, have shown Vygotsky to be superior to Piaget in accounting for data regarding egocentric speech. Kohlberg, Yeager and Hjertholm (1968)

investigated the relation between egocentric speech and intelligence and maturity of interaction with peers. They also looked at the relation between egocentric speech and task difficulty. Vygotsky's theory predicted more private speech (Kohlberg's terminology) amongst brighter than average children at the younger age studied (4 yrs.) and the reverse for older children (6-7 yrs.). Piaget's theory predicts less private speech amongst the brighter children at both ages. The results were as Vygotsky's theory required. With regard to the maturity of interaction with peers (communicative speech and a rating for cooperative attitude were the measures) Piaget's theory would predict that egocentric speech should reflect incapacity or disinterest in social communication. Vygotsky's theory is consistent with a positive correlation between egocentric speech and social speech. The study revealed a positive correlation. It also revealed (in $4\frac{1}{2}$-5 yr. olds) an increase in egocentric speech with task difficulty. To answer the objection that this result could be explained by assuming that egocentric speech was simply an expression of frustration, Kohlberg was able to utilise the following fact: although three tasks evoked egocentric speech in proportion to their 'cognitive' (as distinct from, say, manipulative) difficulty, a fourth 'non-cognitive' task, which was a difficult one, did <u>not</u> evoke much egocentric speech. (The task was building a tower from blocks. Its

difficulty was assessed by the same criterion as the other tasks, namely the number of Ss spontaneously calling it difficult.)

The situation is, then, that much of Vygotsky's theory seems to be reasonably substantiated.   Before looking at Luria's elaboration of the Vygotsky picture it would be appropriate to examine very briefly the way in which the doctrine of the self-regulating function of speech has been developed by non-Soviet theorists. The development of this idea by the early behaviourists will help to provide a basis against which to judge Luria's theoretical position.

The early behaviourist Dashiell (1927) referring to verbal utterances says, "once built up as social stimuli and responses they become modes of self-stimulation as well, and the reactions of the individual human organism come to be directed to some degree by them" (p. 486). Goss (1961) in his account of the history of the idea of the verbal mediating response offers a quotation from Weiss (1929) which illustrates in more detail the behaviourist idea of self-regulation.

> The speech mechanism that produces food
> [presumably the word 'food' DB] thus serves
> two purposes: (1) the sound of the word food
> may act as a stimulus to prepare the individual
> to react....   (2) The sight of any new object
> which resembles the edible food objects but for
> which the individual has not learned a specific
> handling reaction, may release the reaction
> food and this in turn the repertory of food
> handling sensory-motor mechanisms....
>
> (Weiss, 1929, pp. 318-319)

Language, then, not only functions as a signal of signals but also intervenes to produce responses which, it is claimed, would not have been evoked except by its mediation. The relationship of the above to the basic Vygotsky model can be seen by the fact that the first purpose served by language on Weiss' account deals with the case of a person hearing the word 'food' from another, whereas the second case is that of someone eliciting motor responses from themselves by virtue of their having uttered a word. Despite the similarity with Vygotsky's picture it will become clear that the early behaviourist account differs from that developed by Luria. Luria has attempted to spell out the details of the relationship between speech and motor responses in young children in such a way as to both extend the scope of Vygotsky's ideas and to put them on a firmer experimental footing. In speculating about the possible mechanisms at work he has appealed both to neo-Pavlovian concepts and also to the notion of 'feedback' from cybernetics.

Luria's Development of Vygotsky's Theory

A central theoretical point in any scheme such as Vygotsky's is that if the speech system is to regulate the motor responses in such a way as to permit them to achieve a level of performance of which they would be incapable on their own, then the disorganisation present in the motor system must not be present in the system

doing the regulating.   Let this condition be called
'The Vygotsky Condition'.   Luria has made a number of
experimental claims which can be seen as furthering the
task of showing that, and why, the Vygotsky Condition is
indeed fulfilled.   For example he claims that in 3 to 4
year old children the ability to give verbal responses,
such as saying 'go', to sequences of blue light signals,
whilst inhibiting this response for interspersed yellow
signals, is greater than the ability to perform the
corresponding motor task where the response is pressing
a small rubber bulb (1961, p. 45).   Luria then attempted
to use the "more perfect neurodynamics and greater
controllability" of the verbal system to regulate the
motor responses.   Such a process of regulation is said
to take place when a child of this age performs both the
verbal task and the motor task at the same time.   The
result, according to Luria, is that the motor response
improves as a result of being accompanied by the verbal
response (1961, p. 46).   It is not, however, the meaning
of the word 'go' or 'press' or whatever is uttered, which
exercises a controlling function over behaviour.   The
control at this stage is held to be grounded in the
physiological excitation underpinning the verbal response.
One immediate result of the non-specific nature of the
controlling influence is that to say 'don't press' has
the same impelling result as to say 'press', in that it
provokes a motor response.   Luria claims that this
deduction is supported experimentally (1961, pp. 57-8).

Only at a later stage does verbal regulation utilise the semantic rather than the impulsive aspects of speech (this part of Luria's theory will be elaborated at the end of the chapter).

How does Luria conceive of this process of very basic regulation working? The answer is to be found in what he offers as "the first and simplest model of a voluntary movement in a very young child" (1961, p. 38, Luria's underlining). This model consists in an experimental situation just like those discussed above where a child makes a motor response to a sequence of stimuli, except that when the child makes the response he receives distinct exteroceptive feedback - say from a buzzer - which functions as an external sanctioning signal.

Luria accounts for the relatively poor performance of young Ss on the motor, as distinct from the verbal, task by suggesting that the proprioceptive feedback from the muscles of the hand is inadequate for the purposes of fine control. Luria therefore introduced the exteroceptive feedback to ensure that the feedback loop was completed. The results of experiments attributed to S.V. Yakovleva are reported in which, for example, 75% of children aged 2-3 years showed a complete disappearance of intersignal pressure and clear cut, well co-ordinated reactions to a sequence of signals (there were no signals which required an inhibition of response in the experiment reported). Removal of the

feedback led to a decline in performance. The intro-
duction of feedback thus has marked effect, and this is
crucial to the development of Luria's argument. The
next step in this argument is to say:

> the most essential and fundamental fact,
> characteristic of this stage (3-4 yrs. DB) of
> the child's development, is that <u>similar
> results can be obtained if we replace the
> external sanctioning afferentation by the
> child's own speech</u>... <u>we replace the
> regulatory action of the external signal</u> by
> the child's own verbal commands, which, owing
> to its more perfect neurodynamics and greater
> controllability, now becomes a good regulating
> mechanism.

(Luria, 1961, p. 46, Luria's underlining)

In summary, Luria's argument is in two parts: (1) feed-
back greatly improves performance; (2) the feedback
effect can be taken over by the child's own voice. The
role of speech is to be understood by modelling it on
the feedback experiment. The voice makes man into a
cybernetic system, a self-regulating mechanism, to use
Pavlov's famous phrase which Luria quotes.

Although Luria leaves his readers in no doubt that
the external feedback arrangement is to provide a model
for understanding the regulatory function of speech, a
certain amount of obscurity still lingers. After all,
the exteroceptive feedback is <u>consequent upon</u> the motor
response being made, and it has its source <u>outside</u> the
person responding, whereas the voice seems to be a
system which is working in <u>parallel</u> with the motor
response, and is coming <u>out of</u> the person in the same
way as is the motor response. These difficulties may
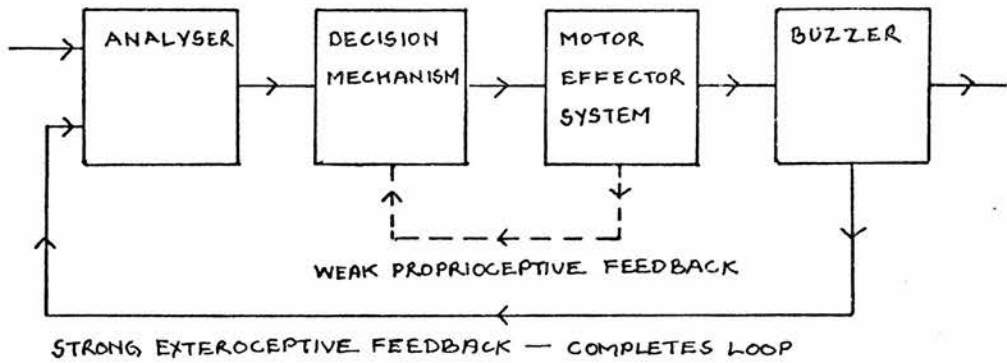
(a) THE BUZZER EXPERIMENT
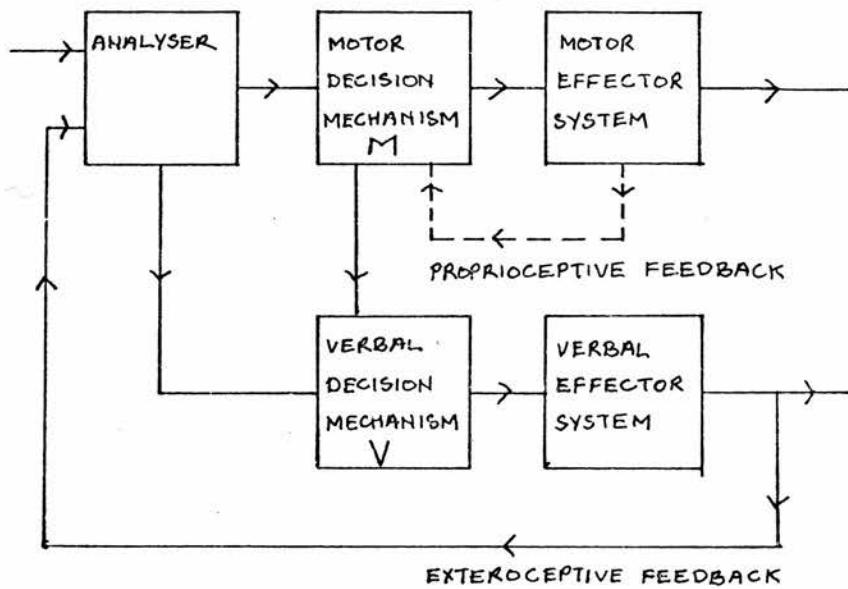
(b) THE MODEL

LURIA'S FEEDBACK MODEL OF VERBAL SELF-REGULATION

FIG 1

be examined in more detail by appeal to pictures of what
is happening within the responding person.   Consider
the schematic and hypothetical arrangement of Fig. 1.

Fig. 1(a) is the case where poor proprioceptive
feedback is replaced by good exteroceptive feedback.
Fig. 1(b) is the case, requiring clarification, of the
verbal system apparently playing an equivalent role.
Assume, for the sake of the argument, that the motor
decision mechanism (M) can link itself to the verbal
decision mechanism (V) in a completely mechanical manner
(like the response bulb and the buzzer) so that a
'decision' of M's becomes a 'decision' of V's.   In this
case the exteroceptive feedback from the voice will be
reliably linked with a motor decision, just as the sound
of the buzzer was;   so the feedback loop will be closed
in a manner closely resembling the model.

Even now, though, not all the obscurities have been
cleared up because a number of questions of detail can be
raised.   It has been assumed that M (the motor system)
can form links with V (the verbal system).   Unless this
is going to be a completely arbitrary stipulation there
must be a general rule to the effect that decision
mechanisms can link themselves together.   But in this
case surely V (the verbal system) could link itself to M
(the motor system), so that another arrow must be added
to the diagram, this time going from V to M.   If this
were the case there would be an internal feedback loop,
and the completed loop would not need to have an

exteroceptive component. As soon as the Vygotsky
Condition was satisfied (that is, the speech system is
adequately developed) it would be ready to work
implicitly without any exteroceptive component at all.
This would run counter to Luria's position in two ways.
First, Luria has always stressed the spoken and explicit
responses of the verbal system. He would insist, as
Vygotsky insisted, on the necessity of a function
developing explicitly and publicly before it can develop
implicitly and privately. The idea of implicit speech
(i.e. the internal speech 'decision' without its motor
component) having a function which has not evolved from
a public function would be unacceptable; so the extero-
ceptive loop cannot be dispensed with right from the
start. Secondly, Luria has remarked upon the fact that
getting a child to whisper, and so cutting down the
exteroceptive feedback, destroys the regulatory function
of speech. The analogy with the buzzer experiment
would point to this conclusion, but what is emerging is
the difficulty of squaring this superficial similarity
with the details of the diagram (b).

The problem, then, is that either a one-way link
from M to V must be assumed, which is arbitrary, or else
a two-way link must be assumed, which seems to dispense
with the need for exteroceptive feedback, which means
that the theory contradicts the model of which it was
supposed to be an elaboration.

There is difficulty, then, in making clear what has

been called premise (2) of Luria's argument: that the
feedback effect is taken over by the child's voice.
But purely theoretical objections may be limited by
suppressed premises and assumptions, and looked at from
another perspective the difficulties may disappear.
What is required is an experimental examination of
premise (1) to see if feedback really does improve motor
performance. If it does not have this effect then the
question does not even arise of whether external feed-
back can provide a model for the regulatory function of
language. The first experiment will check up on these
facts.

An early version of Luria's theory is described in
his book The Nature of Human Conflicts (Luria, 1932).
A look at this detailed account will help to fill out
the picture that Luria is proposing.* Here (especially

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* In the earlier chapters of his 1932 book Luria developed
an objective technique for the study of the emotions.
He used a word association test in conjunction with a
simple motor response from one hand and a measure of
tremor from the other. He argued that the kymograph
trace of the motor response reveals the details of the
central associative processes, for example the develop-
ment of affect or the inhibition of a verbal response.
The cooperation of the Soviet police in providing Luria
with criminals as experimental subjects make it tempting
to think that he was in fact trying to develop a 'lie-
detector'. Runkel (1936) performs an amusing experi-
ment in which the Luria technique is used for this
purpose, with a certain degree of success. The
clinical, though not the forensic, potentialities of
Luria's method have attracted some Western workers who
have "shown the essential correctness of Luria's thesis"
(Clarke,(1955), whose paper, along with Morgan and Ojemann
(1942), provides references to this work). The present
study will not concern itself with the role of emotion as
a source of motor disorganisation, except indirectly at
one point via the concept of 'arousal'. Later
discussions of arousal, e.g. Duffy (1957) and Malmo (1957),
in effect developed a theme of Luria's which he first
investigated some twenty years earlier.

in Chaps. 10 and 11) Luria was already working with
children and using an experimental arrangement similar
to that described earlier, i.e. Ss pressed a rubber bulb
in response to a sequence of light signals. By this
time he had also developed the thesis that language
exerts a regulatory function, but he used the analogy of
a 'shunting' process to illustrate the relation between
the two signal systems (1932, p. 421). Luria here may
be referring to a 'shunt' in an electric circuit which
is often fitted across a galvanometer and is simply a
piece of low resistance wire designed to carry most of
the current so that the instrument is not damaged. It
is a matter of conjecture whether it was explicitly the
electrical analogy that Luria had in mind, but quotations
will show this accords well with the imagery he uses.
The way that this analogy fits into his thinking will now
be examined.

The motor system in a child is characterised, up to
the age of about 6, by a 'diffuseness' which Luria
pictures as an uncontrolled spreading of excitation in
the brain. In other words, a stimulus does not function
selectively in triggering just this response but not that.
Further, a response cannot easily be delayed or produced
in a standard form to signals of varying length or
intensity. With training and growth these deficits are
overcome but the path taken to achieve greater control
and organisation is viewed by Luria in a novel way. It
is not achieved by means of the gradual accumulation of

well-conditioned S-R connections (growth from below, as
Luria calls it) but rather by the intervention of higher
cortical processes.   The intervention of these higher
processes with their 'intricate and labile system of
making connections' (1932, p. 349) permits the develop-
ment of what Luria calls a 'functional barrier' between
the stimulus input and the motor decision mechanism.
This functional barrier prevents the 'overloading' of
the motor system and is responsible for the 'shunting'
of the excitation into the verbal system.   This Shunt
Model, as it will be called, is captured in the
following quotations:

> The explanation of the structure of the
> reactive process brings us to a scheme
> differing somewhat from the usual, the scheme
> of the reactive arc.   The given stimulus
> evokes in the system a certain excitation;
> reaching the central apparatus, it, however,
> is not connected directly to the motor system,
> but is restrained by some 'functional barrier',
> and after the definite preliminary elaboration
> as a result of which there comes about a
> linking-up to the motor system, and the motor
> reactions do not show traces of that 'over-
> loading' characteristic of the preliminary
> central process.

(Luria, 1932, p. 349)

> We come to the conclusion that between the
> stimulus and the reaction in the adult lies a
> certain regulating mechanism which causes a
> corresponding transfer of excitation to the
> motor path, but does not admit to the motor
> system the whole quantity of excitation which
> was produced by the stimulus.

(Luria, 1932, p. 342)

This account is illustrated in Fig. 2 (a) and (b).

Although this picture is still vague it does not

suffer from the initial difficulties associated with the Feedback Model. It does, though, depend crucially on the Vygotsky Condition, which here takes the form that the verbal system, because it can act as a shunt bearing the bulk of the excitation produced by a stimulus, must be better organised (less 'diffuse') than the motor system.

So far two rather different accounts of the details of the process of verbal self-regulation have been presented, which have been labelled the Feedback and Shunt Models respectively. It may be thought that the existence of two models reveals an inconsistency in Luria's theory. Perhaps the best response to this situation is to see both models as tentative articulations of an overall approach which is capable of being extended in a variety of directions. The ideas so far discussed can be arranged in a hierarchy. At the top, on the most general level, comes Vygotsky's thesis. This sees language as being the means whereby problem situations are analysed and courses of action elaborated. Language serves the function of steering behaviour. Luria's work comes on a lower level of generality. He is trying to press Vygotsky's thesis of verbal regulation into service in explaining the execution of the tasks already set for behaviour. This second level of generality emerges in the claim that language is involved in the organisation of ongoing motor responses. Much of what Luria says consists of claims on this level of

SHUNT

LOW RESISTANCE WIRE

BULK OF CURRENT

G

GALVANOMETER

AN ELECTRICAL SHUNT

VERBAL SYSTEM

'SHUNT'

BULK OF EYCITATION

FUNCTIONAL BARRIER

ANALYSER

MOTOR DECISION MECHANISM

MOTOR EFFECTOR SYSEM

PREPARATORY PHASE

EXECUTIVE PHASE
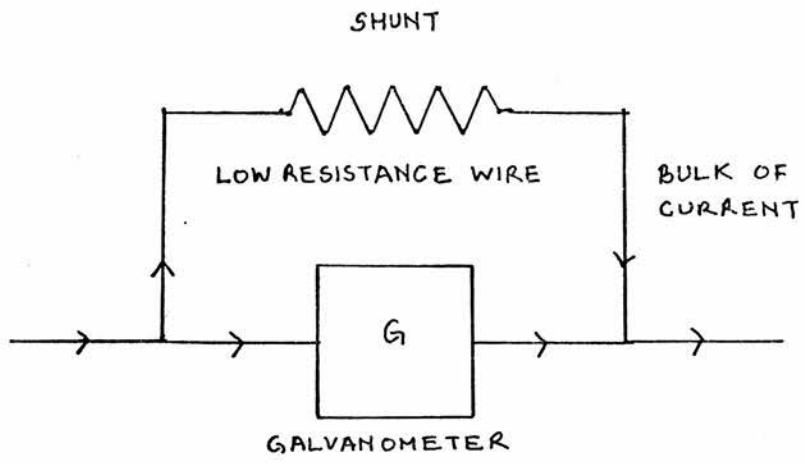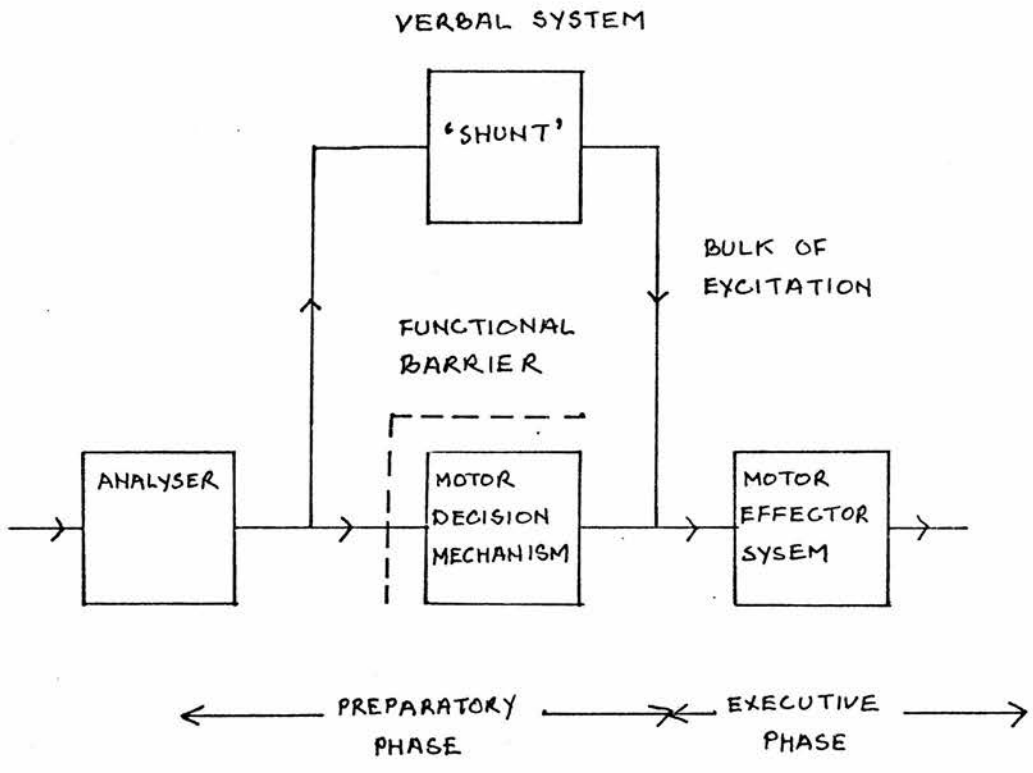
LURIA'S SHUNT MODEL OF VERBAL SELF-REGULATION

FIG 2

generality; and more will be said about these formula-
tions at the end of this chapter. The third and lowest
level in the hierarchy consists in specific claims about
the details of the processes postulated above, and it is
here that the two models are encountered.

Two Criticisms

Before passing on to the experimental part of the
study there are two outstanding points to be dealt with.
The first point is that the Vygotsky-Luria picture of
language has already been subjected to an experimental
attack (Jarvis, 1963) and the results require comment.
Next, there is a quite general argument due to Broadbent
(1958) which may be thought to rule out a priori anything
even resembling the Vygotsky-Luria theory, and this
clearly requires examination. First the theoretical
point will be considered and then the experimental one.

(a) The Broadbent Objection

In considering the relation between verbal and
bodily responses (p. 47) Broadbent remarks on the
different capacities of men and animals to perform pre-
determined sequences of actions. For example, monkeys
find it very difficult to solve problems that require
them to learn to perform a sequence of responses in a
certain order. The superiority of man in this respect,
says Broadbent, is often attributed to the use of
language, because men appear to solve such problems by
formulating a rule and using it to guide their actions -

and this, of course, is the thesis that language has a regulatory function. In Broadbent's view such an explanation puts the cart before the horse. It is not that we can solve problems of this sort because we have language, he argues, but because we have large enough nervous systems, and this in turn is why we possess language.

This argument was not directed explicitly against Vygotsky or Luria, its target was probably the early behaviourists, but clearly a cogent point has been made which requires answering. The force of Broadbent's point can be best seen in connection with the quotation from Wiess given earlier. Broadbent would want to ask Wiess why the verbal system can engage in processes of classification and decision which the motor system cannot. The verbal response presupposes a certain capacity for processing information, so the behaviour has not been explained until the possibility of the verbal response has been accounted for. For theorists such as Wiess and Dashiell working with a S-R theory the problem is particularly acute because the principles of learning are identical for both language and motor responses. A stimulus which is sufficiently different from previous food stimuli should no more evoke the word 'food' than it should food handling responses. For Vygotsky and Luria the problem is not quite so great. To begin with they would be less inclined to insist that the same principles of learning are at work for all

different types of response[*] and in any case there is a
tendency to see the responses coming from two different
systems which are quantitatively, even if not qualita-
tively, different.   This allows a means of escape from
Broadbent's point because there is no reason a priori
why the greater resources of our larger nervous systems
(compared with other animals) should not be invested
differentially in favour of the language system, and
then be exploited by giving language a regulatory
function.

(b)   A Failure to Replicate Luria's Results

Assuming now that the Vygotsky-Luria thesis can get
off the ground at all, the experimental attack will be
considered.   This consists in the failure of P.E. Jarvis
to replicate one of Luria's experimental claims.   Jarvis
conducted a thorough investigation to see if there is 'a
stage of development during which instructing the child
to verbalise...to give himself instructions...whilst
performing a sensory-motor task will improve his
performance if he tells himself what to do, but hinder
his performance if he tells himself what not to do'.
The task involved pressing a button with the thumb when
a blue light appeared.   There were three experimental
conditions: (i) a silent condition, (ii) a push
condition, in which Ss said 'push' when they saw a blue
light and pushed, (iii) a don't push condition in which

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[*] This point is discussed more fully when the general
form of Luria's theory is elaborated at the end of
the chapter.

Ss said 'don't push' whenever they saw a yellow light.
Jarvis' results did not support Luria's hypothesis.
They showed that the child's ability to perform the task
improved with age, but verbalisation, or the lack of it,
had no significant effect on their performance.

This is obviously an important result with
potentially devastating implications for Luria's scheme
of ideas.   Three points about the experiment ought to be
borne in mind, however.   The first point concerns the
extent to which the results are directly comparable.
As Jarvis himself pointed out it is very difficult to
know exactly what Luria and his co-worker actually did,
in detail, in performing their experiments.   Although
some astute detective work on Jarvis' part enabled him
to make a good guess at the speed of presentation of the
stimuli, questions about amount of practice, length of
trials and, of course, more subtle features about the
interaction of the experimenter and the child subject,
were all unknowns.

The second point is that there is an important
feature of Jarvis' experiment about which he gives no
objective information.   This concerns the actual verbal
behaviour of the children during the performance of the
experimental task.   The children in two of the groups
had to utter the word 'push' or the words 'don't push'
very frequently throughout the task.   There is no data
given as to whether they actually did this, or, if they
did, whether they said it aloud or whether they

whispered. It might appear that it can be taken for granted that the children would say this completely unselfconsciously and in their normal speaking voice. The present writer's experience is that it cannot be taken for granted; such a repeated verbal response has a tendency to die away into a whisper, and certain children are very self-conscious about mouthing things aloud in such a curious situation. It is not revealed, for example, if any Ss were rejected because of inhibition of the verbal part of their response. If it is supposed, perhaps quite unjustly to Jarvis, that his Ss tended to whisper then Luria could argue that we might indeed expect the result that verbalising or not verbalising made no difference.[*]

The third, and final point about this important experiment is that it is necessary to realise the scope of the result, even if it is taken, as perhaps it ought to be, as a direct refutation of one of Luria's specific claims. Whilst Jarvis' finding may be the end of some of Luria's picture of language-motor interaction in child development, it does not demolish the less detailed and less tightly-knit framework of Vygotsky's ideas within which Luria worked. The particular experimental results which Luria offers as an exemplification of language regulating behaviour must perhaps be relinquished, but this does not mean that the general

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[*] Experiment 3 of this study, however, constitutes a measure of defence for Jarvis against such a line of argument.

idea of language in some ways and in some circumstances
having a regulatory function must be discarded.   Nor,
of course, does it demolish the recommendation that, if
such a regulatory function be found, it is to be under-
stood in terms of the alleged result of introducing
exteroceptive feedback.   The form of language regula-
tion and interaction with other systems may be more
subtle than to reveal itself in the situations specified
by Luria and checked by Jarvis.   An example of more
subtle modes of interaction is provided by the experiment
of Corcoran (1966).   He found that in a task requiring
Ss to cross out 'e's as rapidly as possible in a printed
passage, there was a tendency to miss 'e's which would
have been silent had the passage been read aloud.   Here
it looks as if the spanning of the acoustic image of the
word is more efficient than, or perhaps merely pre-
dominates over, the result of scanning the visual image.
Alternatively, as Corcoran himself concludes, the response
of crossing out the letter was perhaps facilitated by the
coincidence of the outputs of the visual and acoustic
scanning.   Again, there are results such as Fletcher's
(1962) which point to further kinds of verbal-motor
interactions.   He found that the two-choice reaction
time of 6 year olds was significantly decreased if the
lifting of the response key is accompanied by a spoken
'go'.   The accompanying verbal response, however, was
found to increase the two-choice reaction time of young
adults.

Jarvis' results, though, naturally throw doubt onto the more elementary experiments of Luria's which led up to the one which he tested. These are the very results which Luria presents as showing that the Vygotsky Condition is fulfilled and that feedback has a significant effect. It will be these elementary experimental claims that will now be examined. The focus will then pass on to attempts to find more general experimental tests for the presence of Luria-like links between speech and action.

EXPERIMENT 1. AUDITORY FEEDBACK AND MOTOR PERFORMANCE IN 4 AND 5 YEAR OLDS

In this section an account will be given of an attempt to repeat one of Luria's experiments under clearly stated and appropriately controlled conditions. The hypothesis tested can be stated as:

Hypothesis

The ability of young children to perform the motor task of pressing a rubber bulb to blue light signals but not to yellow light signals is improved by the introduction of auditory feedback produced by the response.

The role of this experiment in Luria's scheme is that (1) it is held to support the idea that the relative inadequacy of the motor system is due to insufficient proprioceptive feedback, and (2) it provides a model in terms of which the role of language

can be understood.

The hypothesis is not stated in fully operational terms. This would be tedious to do explicitly, but will be done implicitly in the following manner. 'Young children' is defined in Table 1 where the $\underline{Ss}$ are described. The word 'ability' will be defined in terms of the number of errors of the different types given in the section on scoring criteria. The term 'improved' also requires definition. The meaning most appropriate to Luria's intention is that if F is the population of scores of those $\underline{Ss}$ given feedback, representing the number of mistakes they have made, and NF is the corresponding population of scores for the $\underline{Ss}$ not given feedback, then NF is stochastically larger than F, or the bulk of NF is higher than the bulk of F (Siegel, 1956, p. 116). The vague specification of the stimuli and feedback will be refined in the sections giving details of the apparatus.

Subjects

The 64 $\underline{Ss}$ were from two local authority schools, the Moray House Demonstration School, Edinburgh, and the Drummond Street Primary School, Edinburgh. The schools were selected because they were situated near the University. The $\underline{Ss}$ were divided into two groups according to age. The older group were drawn from the infant school classes at the two schools mentioned, the younger group from the nursery classes of the Drummond

Street School.   The two groups (N = 32) had equal
numbers of boys and girls.   The mean age for the two
groups is given in Table 1.   No investigation into
educational level or wealth of parents was conducted
though there is no reason to think that constitution of
the two age groups differed significantly in this
respect.   The two schools did not differ in classroom
organisation, both adopted a free regime called 'the
integrated day', with the children working in small
groups.   The experiments were carried out during the
schoolday without parents being present.

No Ss had to be eliminated because of sensory-motor
defects, nor were any Ss known to the teacher to be
colour-blind (visiting school doctors would have
informed the teachers had any child been colour-blind).
One older child was eliminated from the experiment
through unwillingness to perform the experiment; also
eliminated were two of the younger children who were
reluctant to leave their playmates and two who were
unwilling to perform the experiment.   These five are
not counted in the 64 mentioned above.

All Ss were of normal intelligence.   A few days
after they had been given the experimental task they
were given a modified form of the Peabody Picture
Vocabulary Test.   The minor modifications were to
eliminate specifically American words.   Details of the
modification are given in Appendix I.   Since the test
has not been standardised for Britain the mean raw score

is given in Table 1.   The test was used in preference
to established I.Q. tests because of the ease and
rapidity of application.

TABLE 1

Details of the Subjects of Experiment 1

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Test Scores*	S.D.
Younger Ss (Nursery)	32	51.6	7.9	46.5	12.1
Older Ss (Infant School)	32	69.3	3.7	59.1	11.1

* Raw Score.   See Appendix I.

Apparatus

The apparatus was designed to provide the Ss with a
Luria-like situation but was to have the refinements of
uniform and repeatable stimulus presentation and auto-
matic and graphic recording of results, as with Jarvis'
later experiments.

The specifications of the stimulus unit were as
follows: this was to produce flashes of light 0.5 secs.
long on two bulbs in an order which could be specified
before the experiment began and reproduced when required.
The inter-stimulus interval was to be 0.75 secs.   These
values were chosen to correspond to those used by Jarvis,
which were in turn chosen to approximate to those used by
Luria as judged by an examination of reproductions of

kymograph tracings in published papers. Each flash was to be recorded on an event recorder. The experimental run was to consist of 50 flashes, 30 of these were to be blue (requiring a response) and 20 were to be yellow (requiring no response). These ratios were taken from Jarvis. The exact stimulus pattern, which is meant to be random, is given below.

Letting a plus sign indicate a blue light and a negative sign indicate a yellow light the stimulus sequence was:

+ + + + - - - + + + - + + + + - - -

+ - - - + + + + + + + - - - + + - + -

+ + + + - - + - - + + - - + + - -

Stimulus Sequence for Exp. 1

The stimulus bulbs (ordinary torch bulbs) were mounted in a 22" by 22" vertical screen in such a way as to illuminate from behind the eyes of a cartoon rabbit figure drawn onto the screen. The 'eyes' were $\frac{5}{8}$" diameter commercial warning lights made of plastic. The blue light on the right, the yellow on the left. The lights had their centres $1\frac{4}{5}$" apart. The apparatus was such that the lights could be switched on and off manually so that the task could be demonstrated to the Ss.

The lights were actuated by pulses fed from a portable UHER tape-recorder, one channel per light. The pulses, which were put onto the tape by means of a computer, also triggered the event recorder. Pressure from the $1\frac{1}{2}$" diameter response bulb was fed into a

pressure transducer (Penny and Giles, type T.P.8) and
in turn into the event recorder and loudspeaker to
provide a buzzing noise to act as auditory feedback.
The apparatus is presented schematically in Fig. 3.

For the purposes of the experiment the apparatus
was placed in an empty classroom which was sufficiently
far from the others to be free from distracting noise.
The transducer, buzzer, low voltage power supply and
control box were packed behind the stimulus screen out
of the view of Ss.   The tape-recorder and event
recorder were separate behind either a screen or movable
blackboard at the side of the room.   The stimulus
screen was placed on a small table in front of which the
Ss sat holding the response bulb whose connecting tube
emerged from the bottom of the screen.

Experimental Design

Each S was given instructions and training up to a
specified criterion, and then two experimental runs.
The task assigned to S was to press a rubber bulb held
in the hand when he saw a blue light but to refrain from
pressing it when he saw a yellow light.   On the second
of the runs some Ss were given auditory feedback from
their responses in the form of a buzz produced by
pressure on the bulb.   Equal numbers of Ss from each of
the two age groups were used, and half were assigned to
the feedback (F) group, and half to the non-feedback
(NF) group.   Both F and NF groups contained equal
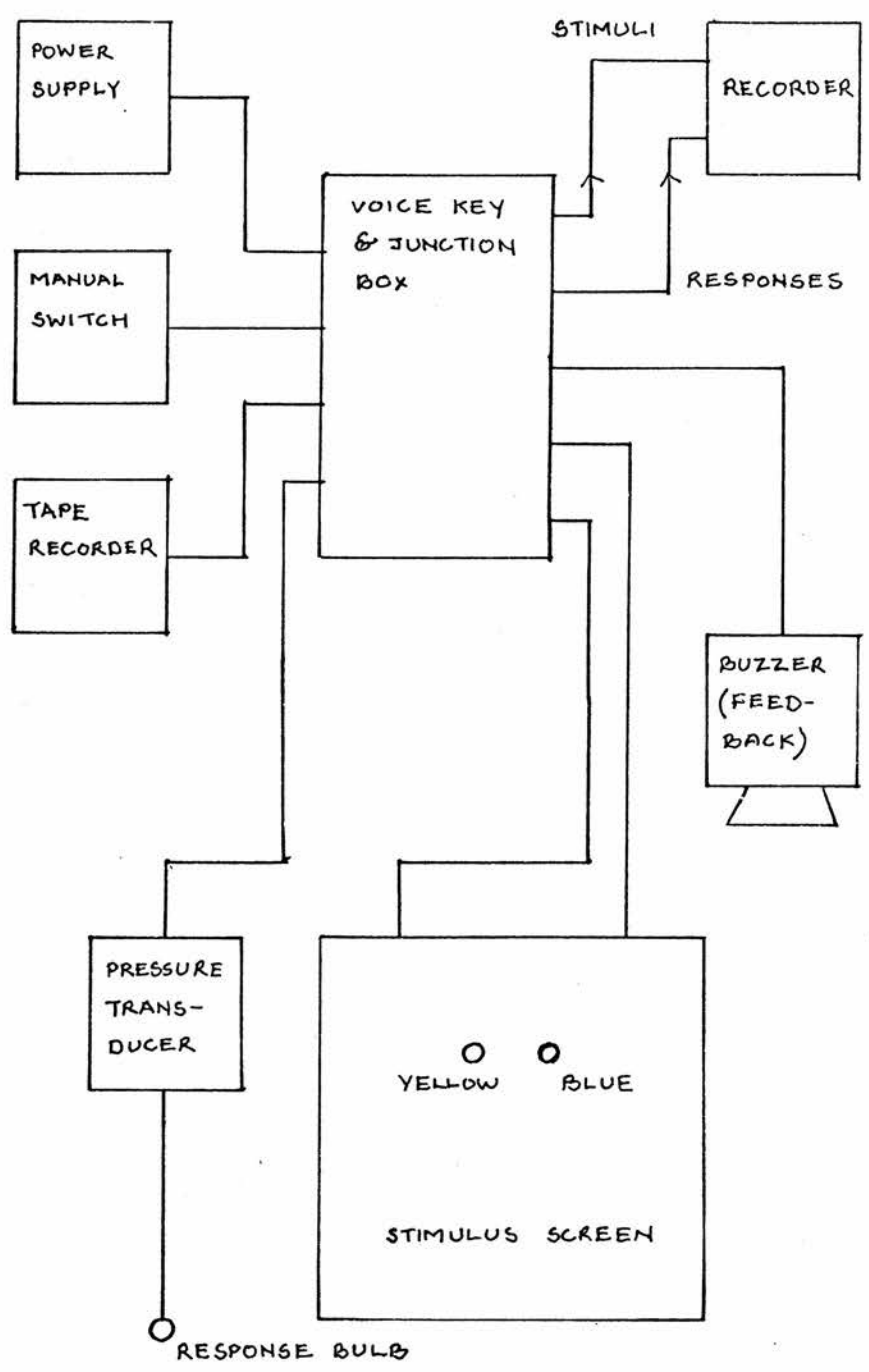
APPARATUS FOR EXPERIMENT 1

FIG. 3

numbers of boys and girls.   Both groups had brief
practice between the two experimental runs, which took
the form of one run up to the criterion.   This was
mainly for the benefit of the F group to accustom them
to the presence of the buzz, but was given to the NF
group to control for amount of practice.   This design
permits comparison of the relative improvement over two
runs of the Ss with and without feedback.   The hypo-
thesis tested predicts that Ss with feedback will
improve more than Ss without feedback.

Procedure

(1)   Introduction of S to experimental situation.

The older Ss were introduced to E in the school
classroom by the teacher who explained that E had an
interesting game that they might want to play.   In both
schools children volunteered instantly to accompany E.
With the younger nursery children, E made himself a
familiar figure in the playroom by a number of
preliminary informal visits.   The children were then
approached to act as Ss through the teacher.   Again
many children volunteered as soon as they knew what was
wanted.

The Ss were then taken by E to the classroom
containing the apparatus and seated in front of the
stimulus screen.   The rabbit figure was indicated and
the children were asked what it was.   Most of them
replied 'rabbit', or 'bunny', though some called it a

dog. The label volunteered by S was then used by E who explained that the figure had funny eyes which winked: the blue and yellow lights were then operated manually to show this. S was then asked to name the colours of the lights when they were presented. Throughout the experiment E used the colour labels volunteered by S in the few cases where blue was called black, or where yellow was called orange. Where Ss occasionally did not know the colour word they wanted to use, colour labels were dropped by E and the lights simply indicated by touching them. Even when colour labels were used by E the use of the colour word was always accompanied by pointing carefully at the relevant light.

(2) Instructions and Training.

It was explained to S that the game was to take hold of the rubber bulb (which was called a 'squeezer') and give it a hard squeeze every time the rabbit winked with the blue eye. (The bulb was to be held in the child's preferred hand.) The instructions proceeded, 'Sometimes the bunny will wink with the blue eye (point at blue eye) and sometimes he will wink with the yellow eye (point), when he winks with the blue eye I want you to press like this....' A sequence of blue flashes were given with the E holding the bulb near the rabbit's face and very obviously squeezing the bulb. The bulb was held near the rabbit's face so that both would be in the child's field of vision. If S had had to look back

and forth at the lights and the E's hand this may have resulted in missing some of the flashes and the correspondence between presses and flashes. Then a mixture of blue and yellow lights were given with E stressing that no squeeze was to be given for the yellow light.

The child was then given the bulb and was able to practise the task. Ss were also asked before they began practising on their own to tell E what they were to do. If S could not formulate the instructions, as many of the younger ones could not, then they were prompted, 'What do you do when this one (pointing), the blue one, comes on?' All Ss were capable of saying 'press' or 'squeeze', and 'don't press' to the further question concerning the yellow light.

Throughout the training period E maintained an encouraging but unhurried manner with plenty of 'reinforcement' for successful mastery of the different phases of the task. The Ss invariably found that they were making mistakes, usually of the form of pressing for the yellow light, and were often amused at being caught out.

During the training E presented the lights manually. Training continued until Ss had reached a criterion, which was to perform faultlessly the sequence, + - + + - + + - , where + indicates a blue light and a press, - indicates a yellow light and no press. Each signal and each gap between signals lasted about one second in this test.

(3)   The Experimental Runs.

The Ss were then told that they would now have the winking eyes put on and off, not by E, but by a machine that would do the job for him so that E would not get tired.   S was to look at the eyes very carefully and remember what he had to do.   E then left the chair by the side of S and switched on the event recorder, which made a slight buzz.   E told S that this meant the lights were going to come on so he must look at the rabbit. When S was looking at the stimulus screen E switched on the tape recorder which actuated the lights.   E then quietly returned to his chair looking at the lights not at S in case this would distract him.   E said 'good' quietly as he sat down to encourage S.   If S turned to E during the experiment, he was gently reminded to look at the eyes and remember what he had to do;   E would himself be looking at the lights not at S whilst saying this.

It was decided to adopt the policy of being seated beside the S for three reasons.   Firstly to construct and transport a cubicle for use by S would be costly and difficult.   Secondly it is not clear that any increase in objectivity is obtained by placing Ss in a situation which may, rightly, arouse their suspicions;   they may spend more time thinking about why they have been isolated and when the isolation will finish than about the task.   Thirdly the experimental situation adopted permits Ss to receive generalized encouragement from E in a natural way.

Between the two runs the NF group received a brief practice run using the test sequence mentioned above. The F group were shown how the pressing of the bulb now caused a buzzer to sound.

Each experimental run lasted about two minutes. The total time $\underline{S}$ was with $\underline{E}$ varied depending on how rapidly the task was mastered. Total time was not recorded but was in the region of ten minutes. $\underline{S}$ was then taken by $\underline{E}$ back to classroom.

Scoring Criteria

As with the stimulus values, the method of scoring the $\underline{Ss}$' performances will be taken from Jarvis, though slight refinements to his criteria will be mentioned.

A response will be defined for the purposes of this experiment as pressure on the bulb by the $\underline{S}$ sufficient to trigger the event recorder. Only an on/off measure was used.

The following five categories into which the responses fell will be quoted directly from Jarvis since he adopted an obvious and logical classification. A blue flash is referred to as a positive stimulus, a yellow flash is referred to as a negative stimulus.

(1) A missing response (M) was scored whenever $\underline{S}$ failed to make a response to a positive stimulus before the onset of the next stimulus, whether positive or negative.

(2) A response to a negative stimulus (N) was

scored for the first response made in the time
between the onset of the negative stimulus and
the onset of the next stimulus.

(3) A late response (L) was scored for the first
response which began between the termination
of the positive stimulus and the onset of the
next stimulus.   If more than one response was
made during this period, only the first was
scored L.

(4) An extra response (E) was scored whenever
there was more than one response made between
the onset of one stimulus and the onset of the
next stimulus, all responses after the first
one during any such period being scored E.

(5) All other responses were considered correct
responses (C).

Although the above categories were used for
classifying responses it was decided to supplement the
comparison of Ss purely in terms of the number of late
responses made.   The reason for this is that the number
of late responses alone is not necessarily directly
indicative of the level of performance.   This is
because both very good and very bad performers could
have a lower L score than a mediocre performer.   The
bad performer will have a low L score because has made
very few responses at all, and the good performer because
his high number of responses were made rapidly.   For
this reason the L score alone, unlike the other

categories, was not felt to be adequate.   Instead, the
ratio of late to correct plus late scores, L/(L+C), was
used.

Occasionally the response trace showed a response
which appeared to begin in exact alignment with either
the end or the beginning of the trace indicating a
stimulus.   In this case Jarvis' definitions above were
modified to the following which give an unambiguous
decision for all responses.

(i)   A response which begins exactly at the end of
a positive stimulus is counted L.

(ii) A response which begins exactly at the
beginning of a positive or a negative
stimulus is assumed to be a response to the
previous stimulus, i.e. is L or N, or is E,
whichever is appropriate.   The justification
for this is that zero reaction times are not
acceptable, though for simplicity the conven-
tion was adopted that all other reaction
times however short were acceptable.

Results

Non-parametric statistics will be used throughout.
A sufficient condition for using non-parametric rather
than parametric statistics is that important assumptions
for the use of the latter are violated.   Two such
important assumptions are that the observations be drawn
from normally distributed populations and that the

variances of these populations is the same, or, at least of a known ratio.   In the case of the data to be dealt with, the distributions depart greatly from normality; further, there is no guarantee that the variances of the populations involved are equal.   For example, for missing responses, if we consider the variances of the improvements over two runs for the feedback (F) and non-feedback (NF) groups we can reject the hypothesis that the variances of the populations from which the samples were drawn do not differ at the 0.01 level of signifi-cance (F = 2.6 with 31 and 31 df, $p < 0.02$).   Further, there is no _a priori_ reason for assuming any particular ratio of variances.

The experimental results will be presented in the following order: (i) analysis of missing responses, M, (ii) analysis of responses to negative stimuli, N, (iii) analysis of the proportion of late responses to the total number of correct and late responses, $L/(C+L)$, (iv) analysis of the number of extra responses, E.   For each score the most important feature will be the relative improvement over two runs of the F and NF groups.

Missing Responses

(1)   First: the performance of Ss as measured by the number of missing responses on their first exposure to the task will be examined.   Luria's work, in conformity with general expectation, predicts that the level of performance is higher for older Ss.   This is,

in fact, the case. On a Mann-Whitney U test the difference is significant at the 0.01 level on a one-tailed test. The first runs of both the F and NF groups are considered together in this case giving a calculated value of U with $p < .01$ on a one-tailed test with nl = n2 = 32.

(2) Male and female Ss will now be compared, dealing with the two age groups separately and combining the first runs of the F and NF groups. Using a Mann-Whitney test the comparison of male and female Ss yields U = 127.5 for the younger group, and U = 122 for the older group. For nl = N2 = 16, on a two-tailed test these are not significant at the .05 level. So male and female Ss do not differ.

(3) The next question regarding the first run is whether the random division of Ss into experimental (F) and control (NF) groups has indeed produced groups which, on the first run, are comparable in performance.

Taking the younger Ss first: comparing the first runs of the male and female Ss separately in the F and NF groups in neither case does the calculated U in a Mann-Whitney test have a probability less than $p = 0.44$ under Ho on a two-tailed test. (Male Ss, U = 31.5, $p < .96$; female Ss, U = 25, $p < .44$; for nl = n2 = 8, on a two-tailed test.) So young experimental and control Ss do not differ, significantly, at the 0.05 level in their first run.

Looking at the older Ss and comparing male and

female $\underline{Ss}$ separately in the experimental (F) and control
(NF) groups, in neither case does the probability of the
calculated U have a value less than .16 under Ho on a
two-tailed test.   (Male, U = 26.5, p < .95; female,
U = 18, p < .16; for nl = n2 = 8, on a two-tailed test.)
So the older experimental and control groups do not
differ significantly at the 0.05 level.

So far the male and female $\underline{Ss}$ have been kept
separate.   They could be combined and the first runs of
the whole of the F and NF groups checked against one
another to ensure that they do not differ significantly.
This will only be done if the differences between the F
and NF groups is in the same direction for male and
female $\underline{Ss}$: for only in this situation might the
combined groups be significantly different whilst the
subgroups are not.   In the present case of missing
responses the difference between the F and NF groups is
in the same direction for both the male and female
younger $\underline{Ss}$.   The overall groups, however, are still
comparable (the calculated value of U = 106.5 which is
not significant on a two-tailed test at the 0.05 level
with nl = n2 = 16).

(4) Improvement over two runs, M score

The first and most noticeable feature of the
relationship between the first and second runs of $\underline{Ss}$
from both the F and the NF groups is how frequently
there is a decline in performance.   For example, 16/32
of the NF $\underline{Ss}$ get worse on the second run, as did 12/32

of the F group.   Although this is an elementary and
obvious fact it is not one which Luria remarks on.   It
is in itself sufficient to show that whatever the
relation between feedback and performance in this motor
task, feedback is unlikely to have a dramatic improving
effect, even if it has a statistically significant one.

Figs. 4 and 5 show the mean improvement over two
runs for the eight different conditions arising from the
two age groups, the two experimental conditions, and the
division into male and female Ss.   Inspection of the
graph shows that feedback seems to have an overall
effect on both the young and the old male Ss, and on the
older females, but not on the younger female Ss.   A
further point the graphs reveal is that the overall
improvement of the older male and female groups is very
similar in the absence of feedback.

The table below, Table 2, gives the results of Mann-
Whitney tests on the various categories of Ss.
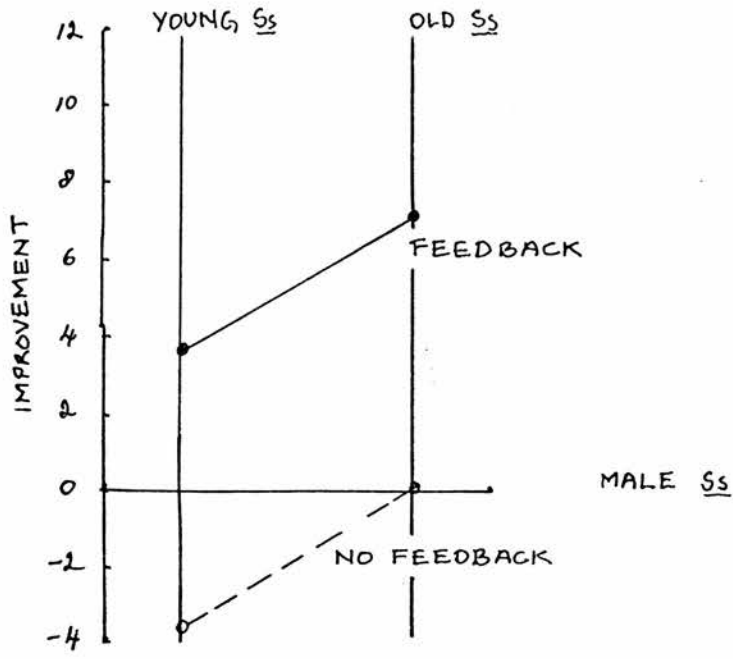
IMPROVEMENT OVER TWO RUNS IN MISSING RESPONSES

FIG. 4
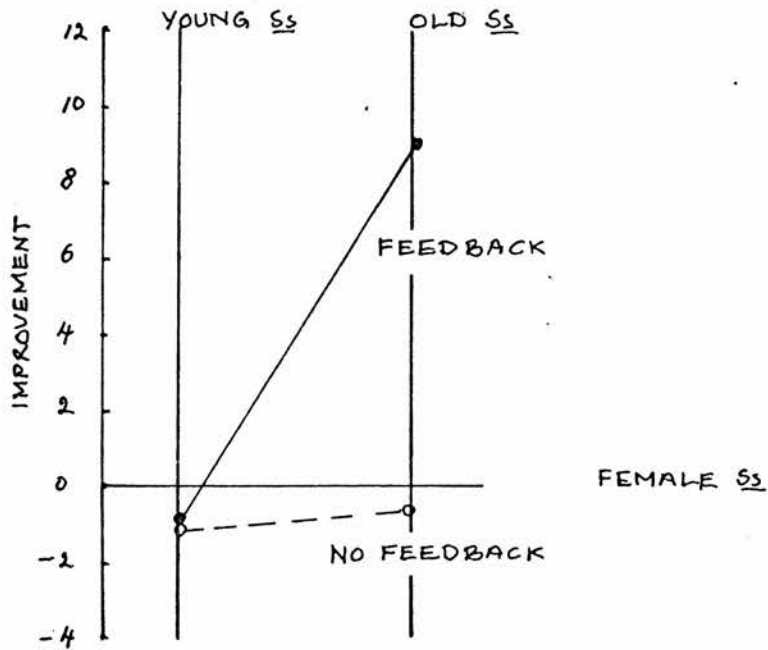
IMPROVEMENT OVER TWO RUNS IN MISSING RESPONSES

FIG. 5

TABLE 2

Improvement in the Number of Missing

Responses over Two Runs

		Results of one-tailed Mann-Whitney tests to see if F groups improve more than NF groups
Younger Ss	Male Ss	the improvement of the F gp is significantly better than the NF gp at the 0.05 level; U = 14.5 p < .041 n1 = n2 = 8
	Female Ss	the improvement of the F gp is not significantly better than the NF gp at the 0.05 level; U = 30.5 p < .439 n1 = n2 = 8
	Combined Male and Female	the improvement of the F gp is not significantly better than the NF gp at the 0.05 level; U = 95, critical value 83 at 0.05 level n1 = n2 = 16
Older Ss	Male Ss	the improvement of the F gp is not significantly better than the NF gp at the 0.05 level; U = 20.5 p < .117 n1 = n2 = 8
	Female Ss	the improvement of the F gp is significantly better than the NF gp at the 0.01 level; U = 10 p < .01 n1 = n2 = 8
	Combined Male and Female	the improvement of the F gp is significantly better than the NF gp at the 0.01 level; U = 61, critical value 66 at 0.01 level n1 = n2 = 16

(5) The next question to ask concerns the relationship between improvement over the two runs and the initial level of performance, and the way that feedback affects this relationship. The information about this relationship for missing responses is given in Figs. 6 and 7. There is a striking contrast between the F and NF groups
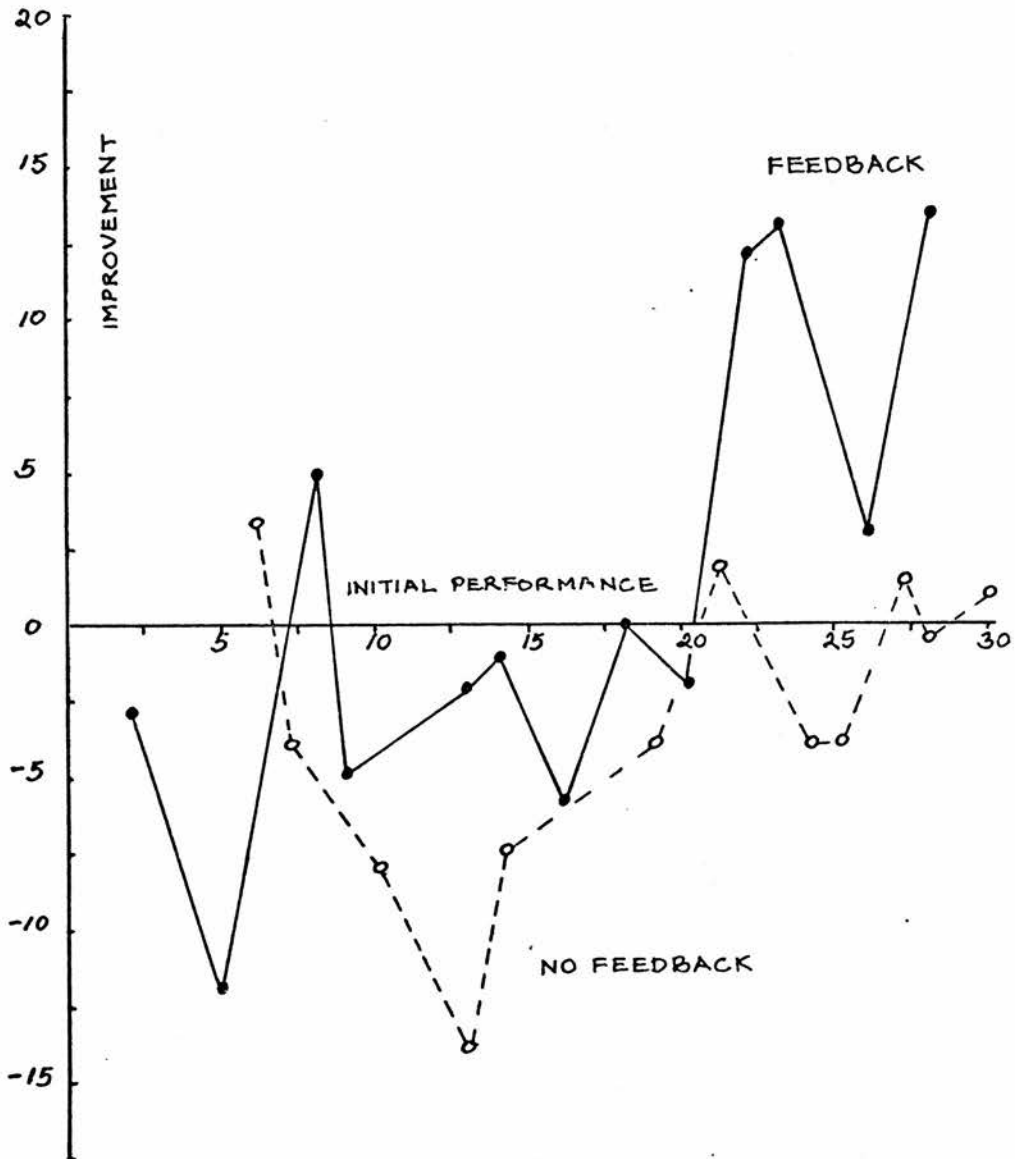
RELATION BETWEEN IMPROVEMENT IN THE
NUMBER OF MISSING RESPONSES AND THE
INITIAL LEVEL OF PERFORMANCE (YOUNGER Ss)

FIG. 6
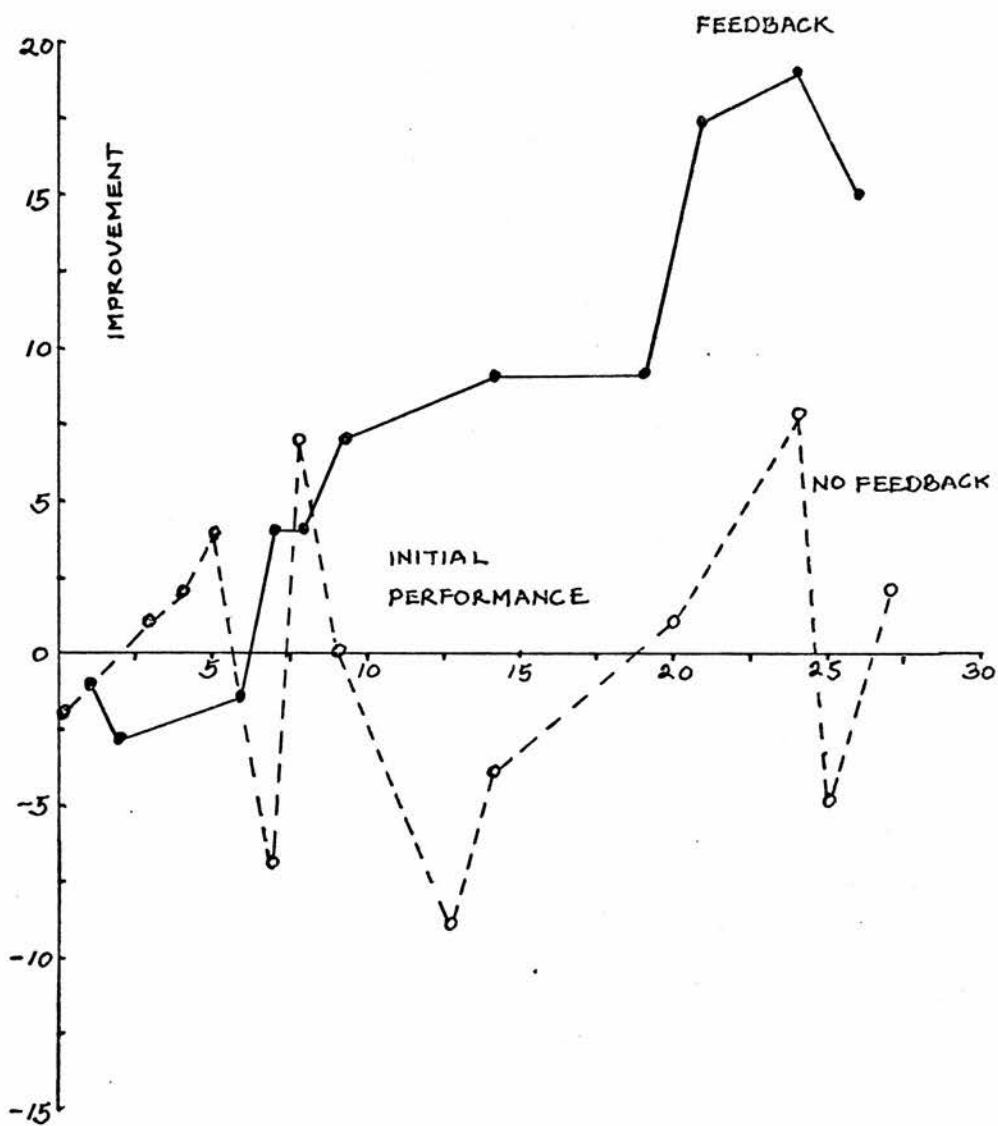
RELATION BETWEEN IMPROVEMENT IN THE
NUMBER OF MISSING RESPONSES AND THE
INITIAL LEVEL OF PERFORMANCE (OLDER Ss)

FIG. 7

for the older $\underline{Ss}$.   There is no discernible relation
between initial level of performance and improvement
for the control groups without feedback, but there is a
clear proportionality between number of mistakes made on
the first run and amount of improvement for the experi-
mental group.   (For the NF group, treating males and
females together, the relation between the initial
number of mistakes and improvement yields a Spearman
Rank Correlation Coefficient of r_s = .2 which is well
short of significance even at the .1 level on a two-
tailed test.*   For the F group, again with male and
females treated together, r_s = .9 which is significant
at the .02 level on a two-tailed test.)   For the
younger group the difference between the F and NF group
is less striking but of the same form as for the older
$\underline{Ss}$.   (For the NF group, combining male and female $\underline{Ss}$
r_s = .3 which is not significant.   For the F group
r_s = .7 which is significant at the .02 level on a
two-tailed test.)

Responses to Negative Stimuli

The approach to the analysis of responses to
negative stimuli will be the same as the approach to the
analysis of the missing responses.   This form will be
adopted for all the remaining measures of performance.

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* The normal symbol for Spearman's Correlation Co-
  efficient is rho, but here Siegal's practice will be
  followed (Siegal, 1956).

(1) Combining the F and NF groups together there is no significant difference between younger and older Ss with respect to the number of responses to negative stimuli on the first run. (On a Mann-Whitney test the probability of the calculated U is $p < .33$ on a one-tailed test with $n1 = n2 = 32$, corrected for ties.)

(2) Looking at male and female Ss separately for the two age groups there is no evidence that the sexes perform differently. (For younger Ss $U = 119$, for older Ss $U = 105$, which are not significant at the .05 level on a two-tailed test with $n1 = n2 = 16$.)

(3) Finally the first run must be examined to ensure that the division of Ss into F and NF groups is unbiased.

Taking the younger Ss first and looking at the male and female groups separately in neither case does the calculated U on a Mann-Whitney test have a probability less than .87 under H_o on a two-tailed test. (Male Ss, $U = 30$, $p < .87$; female Ss, $U = 31$, $p < .96$ for $n1 = n2 = 8$ on a two-tailed test.)

For the older Ss comparing male and female groups separately in no case does the calculated value of U have a probability less than .2 under H_o on a two-tailed test. (Male Ss, $U = 24$, $p < .44$; female Ss, $U = 20$, $p < .23$ for $n1 = n2 = 8$.) Thus the assignment of Ss to the F and NF groups is without significant bias.

(4) Improvement over two runs, N score

The data concerning the improvement of the F and NF

groups over the two runs is given in Figs. 8 and 9.
Again a notable feature of the results is the prominent
number of Ss who decline over two runs.   The graphs
suggest that the younger Ss are better without feedback
whilst the older Ss are better with feedback, in terms
of improvement in performance.   The table below, Table
3, gives results of Mann-Whitney tests on the various
categories of Ss.

TABLE 3
Improvement in the Number of Responses
to Negative Stimuli over Two Runs

		Result of one-tailed Mann-Whitney tests to see if F group improves more than NF group
Younger Ss	Male Ss	the improvement of the F gp is not significantly better than the NF gp at the 0.05 level (U = 14, p < .032, nl = n2 = 8)*
	Female Ss	the improvement of the F gp is not significantly better than the NF gp at the 0.05 level; U = 26.5 p < .287 nl = n2 = 8
	Combined Male and Female	the improvement of the F gp is not significantly better than the NF gp at the 0.05 level (U = 78, critical value 83 at 0.05 level, nl = n2 = 16)*
Older Ss	Male Ss	the improvement of the F gp is significantly better than the NF gp at the 0.1 level; U = 19 p < .097 nl = n2 = 8
	Female Ss	the improvement of the F gp is significantly better than the NF gp at the .05 level; U = 13 p < .025 nl = n2 = 8
	Combined Male and Female	the improvement of the F gp is significantly better than the NF gp at the 0.01 level; U = 64.5, critical value 66 at the 0.01 level, nl = n2 = 16

* The small value of U and p here does not indicate that the
F group is significantly better than the NF group – on the
contrary it arises because the F goup are so much worse
than the NF group.   The observed result is in the opposite
direction to the predicted result on the Luria hypothesis;
see the discussion section.

(5) As with the missing responses the next feature
of the results examined is the relation between improve-
ment over two runs and the initial level of performance.
The graphs below, Figs. 10 and 11, show the results for
the two age groups, and the two experimental conditions
with male and female Ss treated together.   As would be
expected from the form of the graphs the only signifi-
cant correlation to be found between improvement and
initial level of performance is for the older F group
(r_s = .78 which is significant at the .02 level for a
two-tailed test).   For the remaining groups no correla-
tion achieves significance (for older NF Ss r_s = .15;
for younger F Ss r_s = .36, for younger NF Ss r_s = .31).

Proportion of Late Responses

(1) Combining the F and the NF groups together
there is no significant difference between younger and
older Ss with respect to the proportion of late
responses made on the first run.   (On a Mann-Whitney
test the probability of the calculated U under H_o is
$p < .39$ on a one-tailed test with n1 = n2 = 32.)

(2) Looking at male and female Ss separately for
the two age groups there is no evidence that the sexes
perform differently.   (For young Ss calculated U = 80,
for older Ss calculated U = 118.5;   these are not
significant at the .05 level on a two-tailed test with
n1 = n2 = 16.)
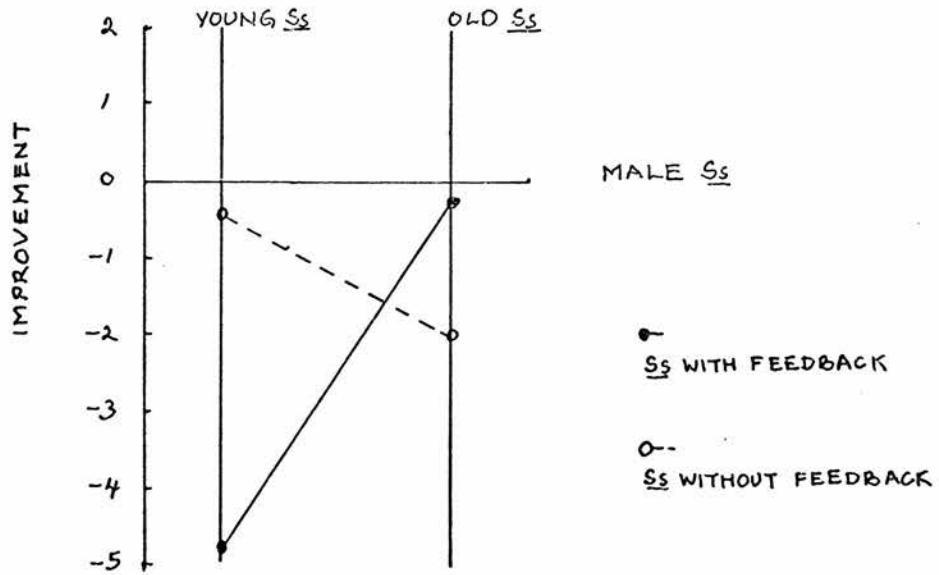
IMPROVEMENT OVER TWO RUNS IN
RESPONSES TO NEGATIVE STIMULI (MALE Ss)

FIG. 8
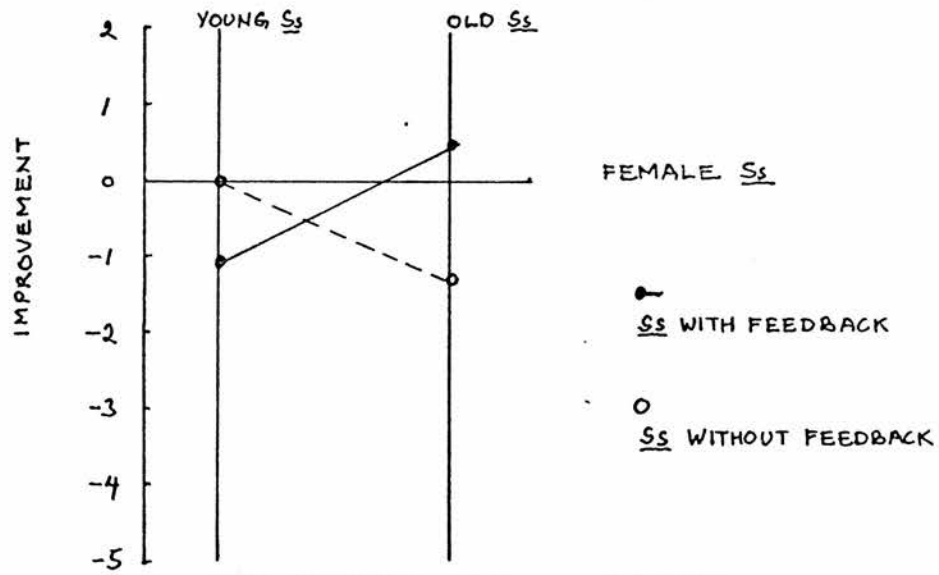
IMPROVEMENT OVER TWO RUNS IN
RESPONSES TO NEGATIVE STIMULI (FEMALE Ss)

FIG. 9
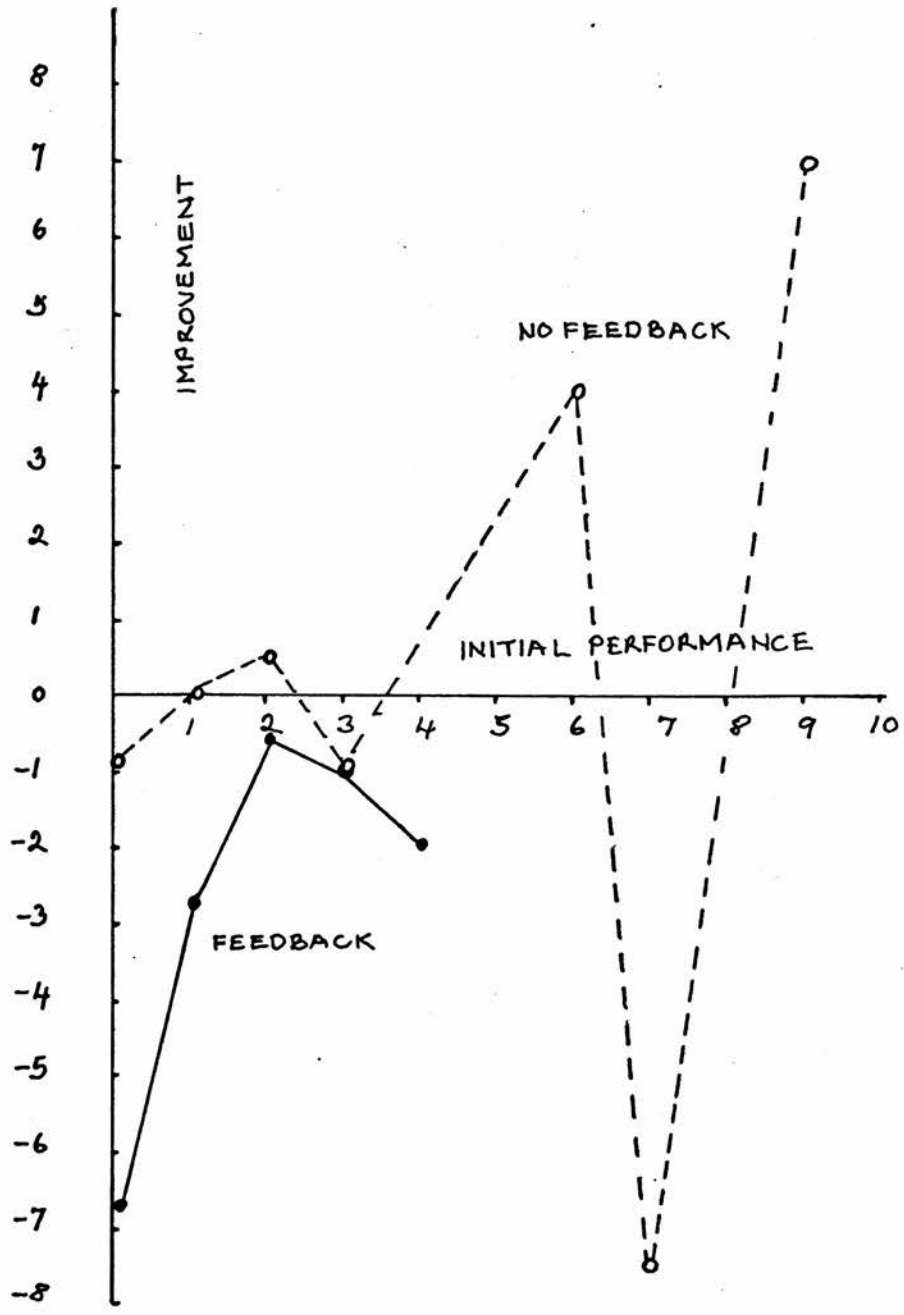
RELATION BETWEEN IMPROVEMENT IN THE
NUMBER OF NEGATIVE RESPONSES AND THE
INITIAL LEVEL OF PERFORMANCE (YOUNGER Ss)

FIG. 10
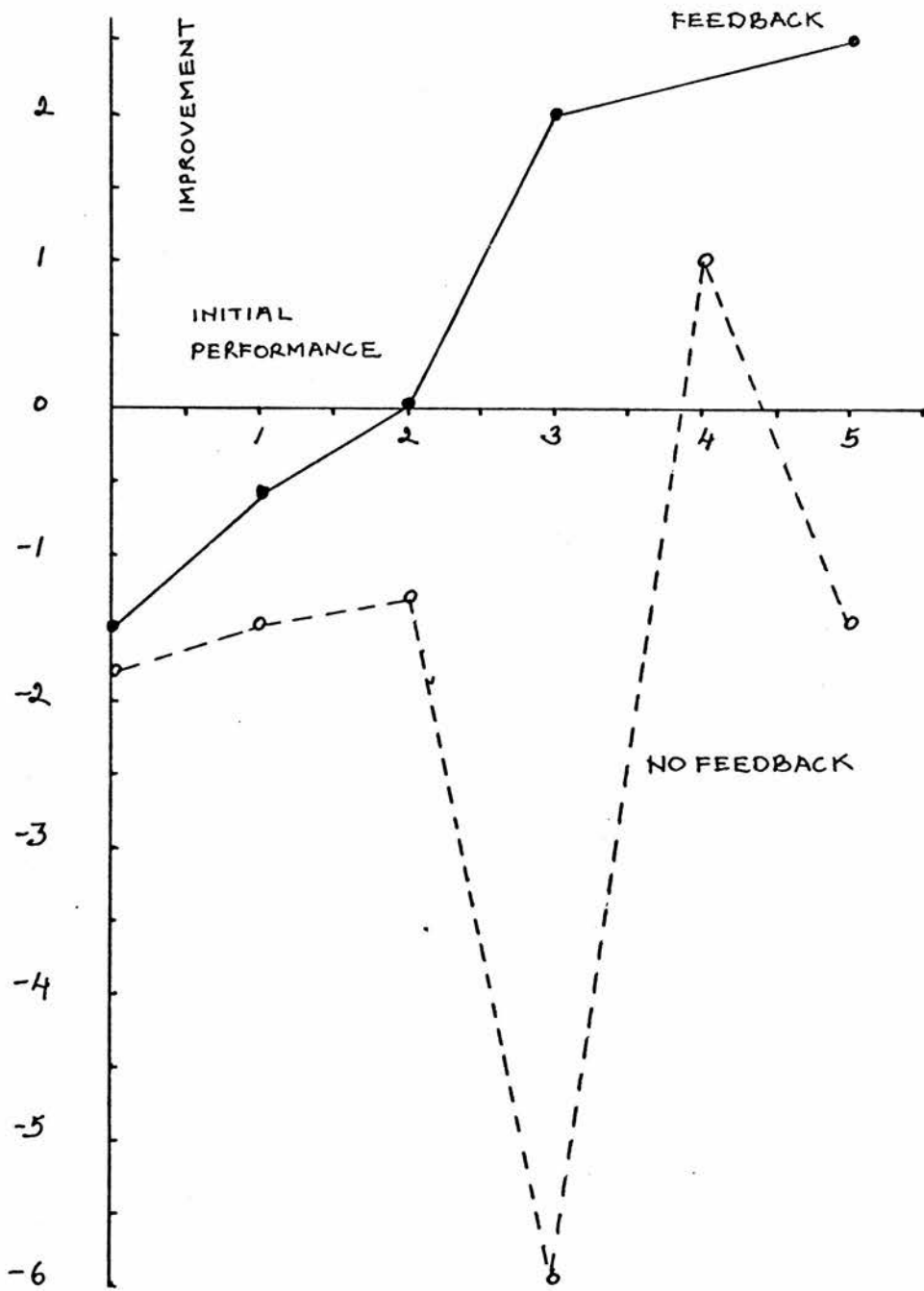
RELATION BETWEEN IMPROVEMENT IN THE
NUMBER OF NEGATIVE RESPONSES AND THE
INITIAL LEVEL OF PERFORMANCE (OLDER Ss)

FIG. 11
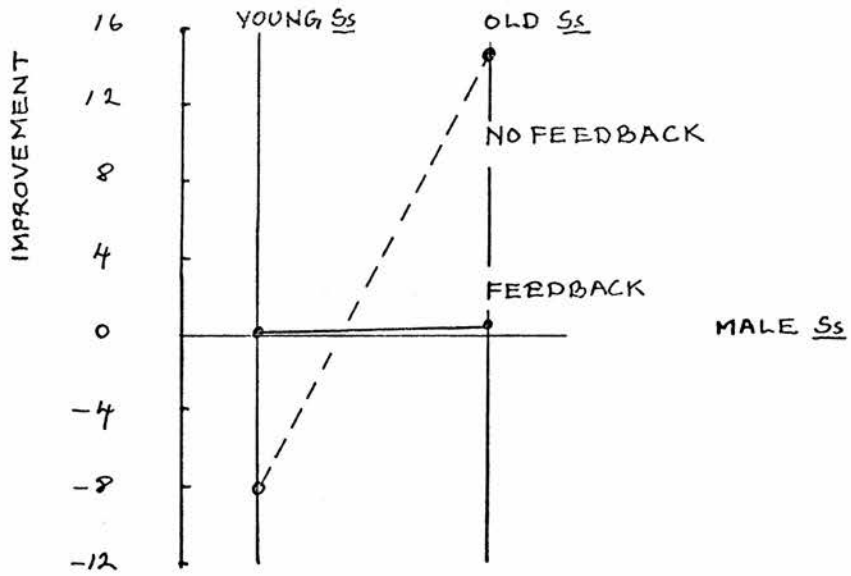
IMPROVEMENT OVER TWO RUNS IN
THE PROPORTION OF LATE RESPONSES (MALE Ss)

FIG. 12
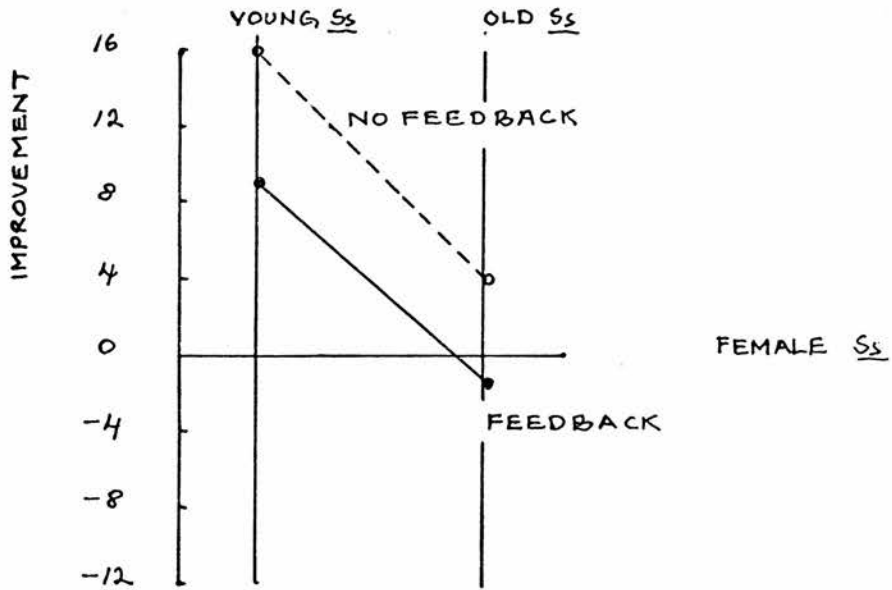
IMPROVEMENT OVER TWO RUNS IN
THE PROPORTION OF LATE RESPONSES (FEMALE Ss)

FIG. 13

(3)   The check for the similarity of control and experimental groups on the first run reveals a snag. The older female NF group are different from the older female F group (U = 13, which is significant at the 0.05 level on a two-tailed test, n1 = n2 = 8).   However, if the control and experimental groups are considered as a whole by grouping male and female Ss together a check on each age group separately shows that on the first run there is no significant difference (for younger Ss U = 118, for older Ss U = 92.5 which are not significant on a two-tailed test at the 0.05 level, n1 = n2 = 16). Because of the lack of comparability of the older female subgroup of Ss the only comparisons that will be made using this measure of performance will use male and female Ss combined.

(4)   Improvements over two runs. L/(L+C) score

The overall improvements of the F and NF groups at the two ages are shown in Figs. 12 and 13.   There are no significant differences at the 0.05 level between the two experimental conditions.   (For the male and female Ss combined the younger Ss give U = 124, the older Ss give U = 86.5, which are not significant at the .05 level on a one-tailed test, n1 = n2 = 16.)   For the older Ss the calculated value of U is not as close to significance as it might appear because the actual tendency of the data is in the opposite direction to that predicted.

(5) In neither experimental or control groups at either age does there appear to be a significant correlation between improvement and initial level of performance. With male and female Ss grouped together the largest calculated value of r_s = .53, which is not significant at the .05 level on a two-tailed test with N = 16. (Young NF, r_s = .53; young F, r_s = .45; old NF, r_s = .03; old F, r_s = .38.)

Number of Extra Responses

The number of extra responses made by Ss with one or two exceptions was very low, often zero. In the first run 41 of the 64 Ss made no extra responses at all, and only one S as many as 5.

(1) There is no significant difference between the number of extra responses for the first run for all the older Ss compared with all the younger Ss. (On a Mann-Whitney test the one-tailed probability of the calculated U under H_o is p $<$ .067, nl = n2 = 32.) This result has been corrected for ties owing to the large number of zero scores. This correction can be taken for granted in all results quoted in this section.

(2) Comparing male and female Ss, there is no significant difference on the first run for either the younger or the older Ss. (For young Ss the calculated U under H_o has a p $<$ .09, for older Ss p $<$ .68 for a two-tailed test with nl = n2 = 16.)

(3) The check for the similarity of the F and NF groups on the first run reveals no significant differences. (Taking young $\underline{Ss}$ first, on a Mann-Whitney test the two-tailed probability of the calculated U under H_o for male $\underline{Ss}$ is $p < .69$, for female $\underline{Ss}$ $p < .74$, nl = n2 = 8 for combined male and female $\underline{Ss}$ $p < .72$, nl = n2 = 16. For older $\underline{Ss}$ males give $p < .44$, females $p < .88$, again on a two-tailed test with nl = n2 = 8.)

(4) <u>Improvement over two runs, E score</u>

There are no significant differences at the .05 level on a one-tailed test between the F and the NF groups. (The one-tailed probabilities of the calculated U under H_o on a Mann-Whitney test for the different categories of $\underline{S}$ is as follows: young males, $p < .44$, young females $p < .12$, combined males and females U = 116.5;[*] the calculated values of U are not significant on a one-tailed test at the .05 level with nl = n2 = 16.)

Figs. 14 and 15 indicate the mean level of improvement for the different groups.

(5) For the NF groups neither young nor old $\underline{Ss}$ showed any significant correlation between amount of improvement and initial level of performance. The old F group, however, showed a significant correlation in that the worse the initial performance the greater the improvement. (For young NF, $\underline{Ss}$ r_s = .16, old NF, $\underline{Ss}$ r_s = .02; for young F, $\underline{Ss}$ r_s = .59, for old F $\underline{Ss}$, r_s = .73. The last value is significant at the .02 level on a two-tailed test with N = 16.) See Figs. 16 and 17.

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[*] Insert: old males $p < .20$, old females $p < .48$, combined male and female U = 116;
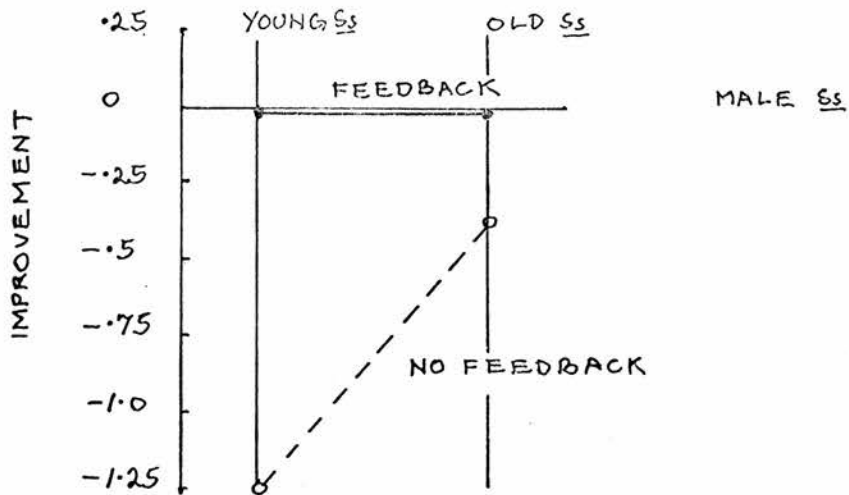
IMPROVEMENT OVER TWO RUNS IN
THE NUMBER OF EXTRA RESPONSES (MALE Ss)

FIG 14
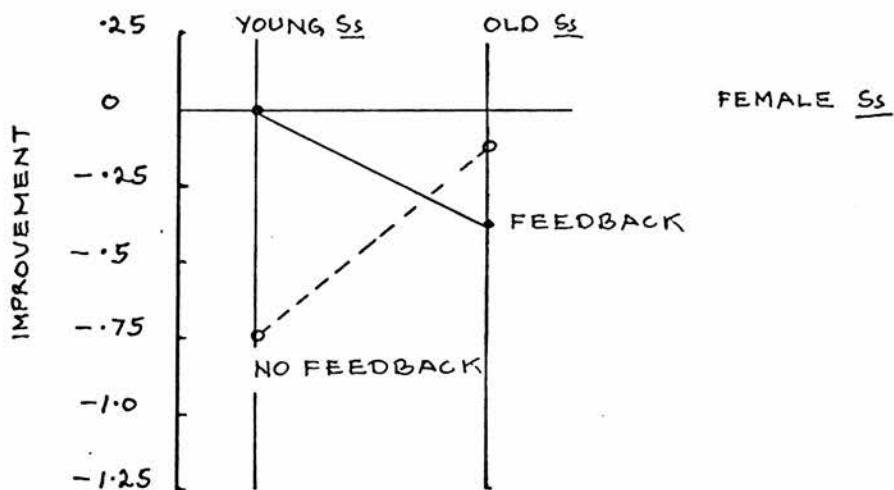
IMPROVEMENT OVER TWO RUNS IN
THE NUMBER OF EXTRA RESPONSES (FEMALE Ss)

FIG 15
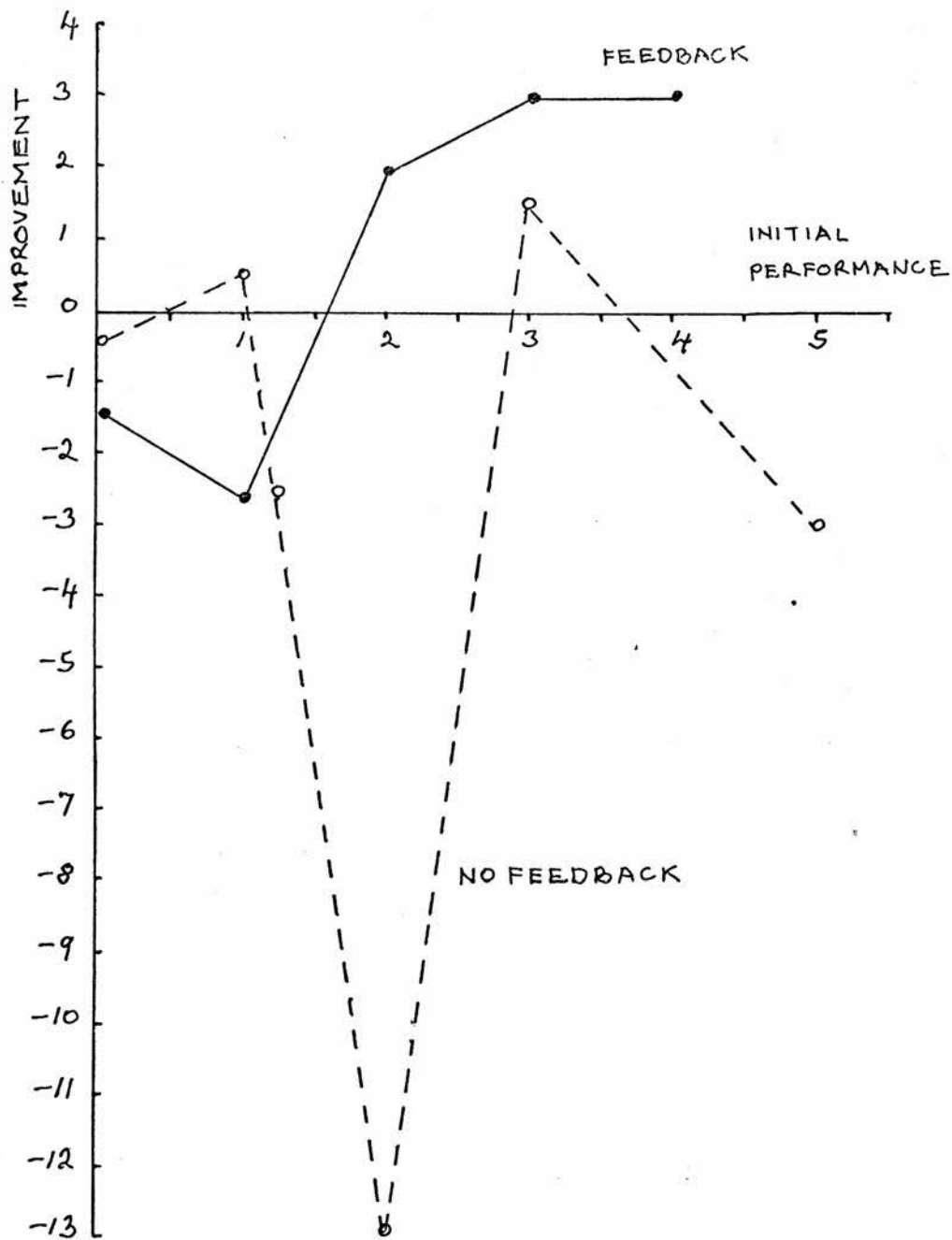
RELATION BETWEEN IMPROVEMENT IN
NUMBER OF EXTRA RESPONSES AND
INITIAL LEVEL OF PERFORMANCE (YOUNG Ss)

FIG 16
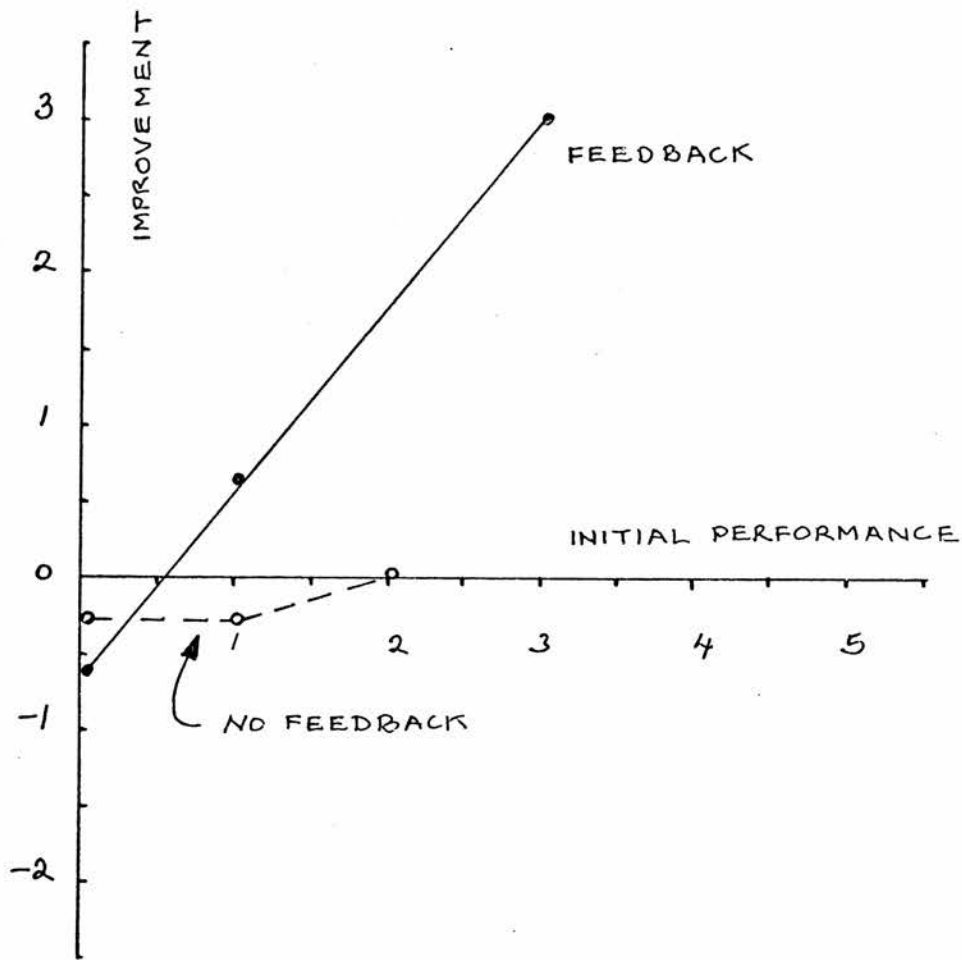
RELATION BETWEEN IMPROVEMENT IN
NUMBER OF EXTRA RESPONSES AND
INITIAL LEVEL OF PERFORMANCE (OLD Ss)

FIG. 17

Discussion

First a summary of the results. With the exception of the number of missing responses age does not influence the initial level of performance. Male and female Ss behaved the same way on the first run for all measures of performance.

With regard to the relative improvements of the Feedback and No-Feedback groups over two runs, there was no significant difference at all on two of the measures of performance: these were the number of extra responses and the proportion of late responses. For the number of missing and negative responses, however, the effect of feedback as shown by improvement over two runs was, in some cases, significant. For both scores the younger Ss taken altogether show no improvement with feedback greater than that shown by controls, but the older Ss taken altogether do show a greater improvement with feedback than without.

Looking now at male and female Ss separately it is found that for the number of negative responses both the older males and older females show greater improvement with feedback than without, whereas neither younger males or younger females do so at all. A similar breakdown for the missing responses is not so neat. The older males, though showing a greater improvement with feedback than without, are not significantly better, whereas the younger males do improve significantly more with feedback. Nevertheless, in the breakdown, three

out of the four groups that show the influence of feed-
back are older $\underline{Ss}$, and grouping males and females
together, as remarked above, shows older but not younger
$\underline{Ss}$ improving with feedback.

Some idea of where the improvement comes from is
given by the fact that for three of the scores (missing,
negative and extra) the older $\underline{Ss}$ with feedback show a
significant correlation between the number of mistakes
made on the first run and the amount of improvement.
Feedback seems to benefit the older $\underline{Ss}$ who had ground
to make up on the first run.

Implications for Luria's Feedback Model

At first sight the implications for Luria's hypo-
thesis would seem to be that in some cases it has been
borne out and in others it has not.   There are, however,
two considerations which make the results seem somewhat
more radically at variance with Luria's ideas.

The first point is that older rather than younger $\underline{Ss}$
make up the bulk of those that show an improvement in
performance as a consequence of having exteroceptive
feedback.   This is not at all what would be expected on
Luria's account of the role of feedback.   Luria
explained the limitations of young $\underline{Ss}$ to perform the
sort of task dealt with in this experiment in terms of
bad proprioceptive feedback.   If inadequate proprio-
ceptive feedback is a characteristic of young children
then the process of physiological maturation would

remedy it; consequently the older the child the better his proprioceptive feedback. This means that the possible help to the child of giving exteroceptive feedback should show diminishing returns. In fact the help given by exteroceptive feedback, rather than diminishing with age, on the whole increases with age. So the results go in the opposite direction to those predicted by Luria.

The second way in which the results differ from Luria's ideas is that not only does feedback often help the older child rather than the younger child, it often appears to make the overall performance of groups of younger children worse. But this point must be heavily qualified because for the younger male Ss feedback does have a significant improving effect on the number of missing responses. Secondly the statement that some groups of younger Ss are worse with feedback cannot be offered as a statistically significant claim.

Although the results of Exp. 1 are not in accord with Luria's predictions they are in conformity with other results concerning age related trends in the ability of Ss to utilise information from more than one source. Birch and Lefford (1967) showed with a figure drawing task that as children grow older they become increasingly capable of treating ancillary visual information as a facilitator rather than a distractor in a motor task. In the present experiment the ancillary information is not visual but consists in the auditory

cues from the buzzer, but as with Birch and Lefford's study children under 6 do not appear to benefit from the extra information.

The impression given by Yakovleva's experiment, quoted earlier, is that feedback has a very marked effect on children's performance.   Such a result is not improbable in view of other reports which have attributed rapid and quite remarkable increases in subtle muscle control to the introduction of exteroceptive auditory feedback, for example Basmajian (1963) and Hardyck, Petrenovich and Ellsworth (1966).[*]   The former experiment in particular (in which single motor units of the right abductor pollicis brevis are brought under the control of the will simply by providing auditory feedback from them) is clearly analagous to Yakovleva's experiment and would point to the result claimed.   The present experiment, however, throws doubt on the idea that auditory feedback is much help to the very young children (such as the younger group in this experiment). Secondly, it throws doubt on the explanation that the limitations in their performance is due to bad proprioceptive feedback.   Third, where feedback does have an effect which is statistically significant its effect on individuals is not a strong one.

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[*] But see the criticisms of the experimental procedure by McGuigan (1967).

An Alternative Explanation

The results so far have been looked at exclusively in terms of feedback as a carrier of information, but feedback can often have an 'arousing' function. The results of this experiment could just as well be approached in terms of the buzzer heightening the arousal of Ss rather than it supplying them with missing information. Broadbent's (1963a) review of work on the interaction of stresses shows that it is plausible to view noise as a source of arousal, and this explanation would fit the general trend of the results quite neatly. Suppose that an increase in arousal helps to improve performance up to a certain point beyond which it detracts from performance. (The mechanism which might underlie this form of the Yerkes-Dodson Law have been outlined by Welford (1962) and Hebb (1955).) Assume as well that the crucial point of inflection corresponds to a higher arousal level the older the child. Given these premises it would be predicted, contrary to Luria, that older children would benefit more than younger children from feedback which increases the level of arousal. Younger children would frequently be at the stage where any increase in the level of arousal would cease to pay dividends and possibly even hinder performance.

A graphic description of the tension observable in young children in reaction time experiments is provided by Goodenough (1935), but it would be wrong to assume

any simple relationship between physiological and
behavioural measures of arousal.   It is known that
sleep-loss, which almost certainly acts to lower arousal
(Broadbent, 1963b) can be accompanied by heightened
muscle tension (Malmo and Surwillo, 1960).   However,
the early work of Duffy (1932a, b) does establish that
in young children muscle tension has an inverted U
relation to performance on discrimination and tapping
tasks.

An arousal theory similar to the one sketched above
is as available in neo-Pavlovian concepts as it is in
standard Western theoretical terms.   Neo-Pavlovian
theory would see the point of inflection as being the
so-called 'threshold of transmarginal inhibition'.
This is the point at which the 'law of strength', which
states that there is a proportionality between the
intensity of a stimulus and the response magnitude,
gives way to the operation of transmarginal inhibition,
where increase in stimulus intensity inhibits response.
This form of picturing physiological processes also
distinguishes 'weak' from 'strong' nervous systems.
A weak nervous system has a lower threshold of trans-
marginal inhibition.   The only extra supposition needed
to make this theory equivalent to the earlier one would
be that the younger the child the weaker the nervous
system (see Gray (1964) for the relationship between
Pavlovian and Western concepts).

Before an arousal theory can cope with the main

trends in the data a refinement needs to be introduced.
So far it has been tacitly assumed that a single
inverted U-shaped curve gives the relationship between
performance and arousal for all performance measures.
This is implausible because different measures of
performance might be expected to respond to over, or
under, arousal in different ways. For example, the
M-score deals with responses which have been missed out
so this score might be expected to suffer no ill effect
from a level of arousal which makes a subject over
responsive. By contrast, the N-score deals with
responses which ought to have been inhibited. In this
case over responsiveness would produce a decline in the
measured performance. The refinement that is required
is a different inverted U-shaped curve for the two
measures of performance. The form of the curves must
be that the curve for the N-score will have reached its
peak before that of the M-score.

Two such curves are given in Fig. 18 (a) and (b).
Consider (a) which deals with the older children in the
sample. Let the line AA' represent the level of
arousal in the first (no-feedback) run, and the lines
BB' and CC' the arousal on the second run with feedback
and without feedback respectively. BB' indicates
heightened arousal produced by the buzzer and CC' a
small decrement produced by slight fatigue or boredom
on the second run with no feedback. These three lines
will produce the main trends of the observed results in

that feedback both decreases the number of responses missed out and reduces the number of responses that should not have been made. Now consider (b) which represents the situation for the younger children who are assumed to be functioning at a higher level of arousal. Let the lines AA', BB' and CC' have the same meaning as above. In this case the effect of the buzzer is to take the Ss level of arousal over the peak of both the curves. The result will be very little change in the number of responses missed (because of the symmetry of the M-curve) but a marked decline in performance as measured by the number of negative responses (because of the relative positions of the curves on the x-axis).

This picture is slightly too simple because it does not differentiate between the male and female Ss who, in the younger group, behave slightly differently. The female Ss on one plausible interpretation of the data are slightly more arousable than the male Ss. This trend, only less marked, can also be discerned in the older Ss. Despite slight oversimplification the arousal theory explains all the main trends in the data and in particular it explains why the younger Ss with feedback show an improvement as measured by the number of missing responses and a decline as measured by the number of responses to negative stimuli. It is worth noting that had the experiment been approached with the arousal picture in mind, as the hypothesis to be tested,

(a) OLDER Ss

PERFORMANCE

C   A   B

MISSING RESPONSE CURVE

NEGATIVE RESPONSE CURVE

LEVEL OF AROUSAL

C'   A'   B'
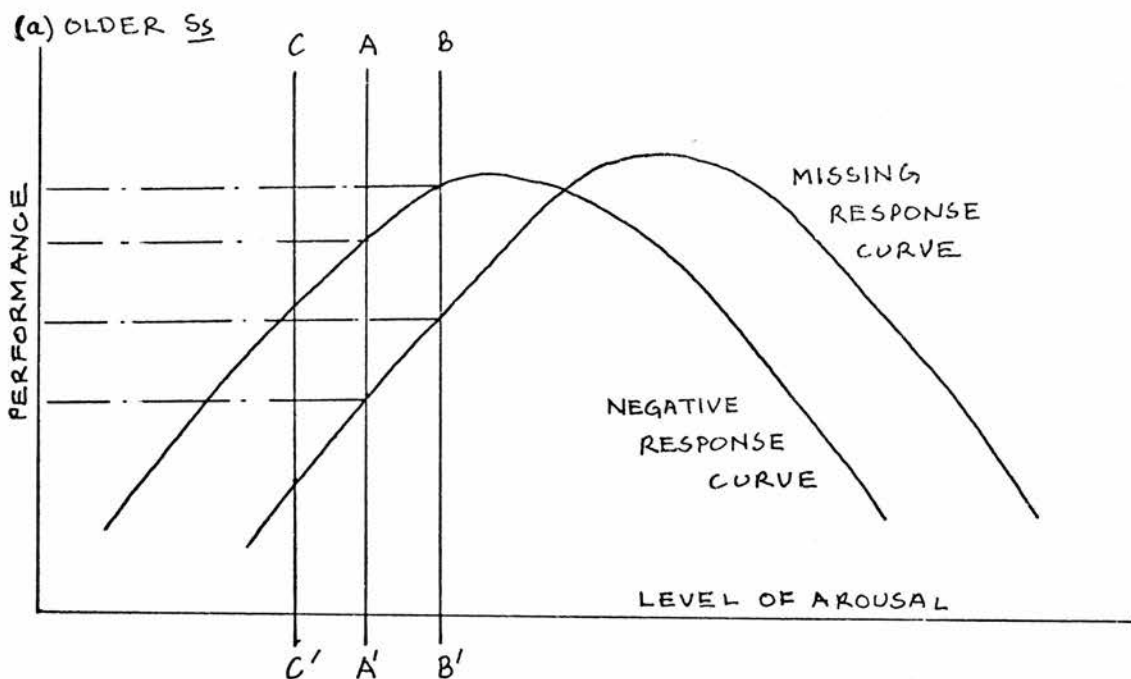
AA'   FIRST RUN
BB'   SECOND RUN (WITH FEEDBACK)
CC'   SECOND RUN (WITHOUT FEEDBACK)
SEE TEXT FOR EXPLANATION OF FIGURES

(b) YOUNGER Ss

PERFORMANCE

C   A   B

MISSING RESPONSE CURVE

NEGATIVE RESPONSE CURVE

LEVEL OF AROUSAL

C'   A'   B'
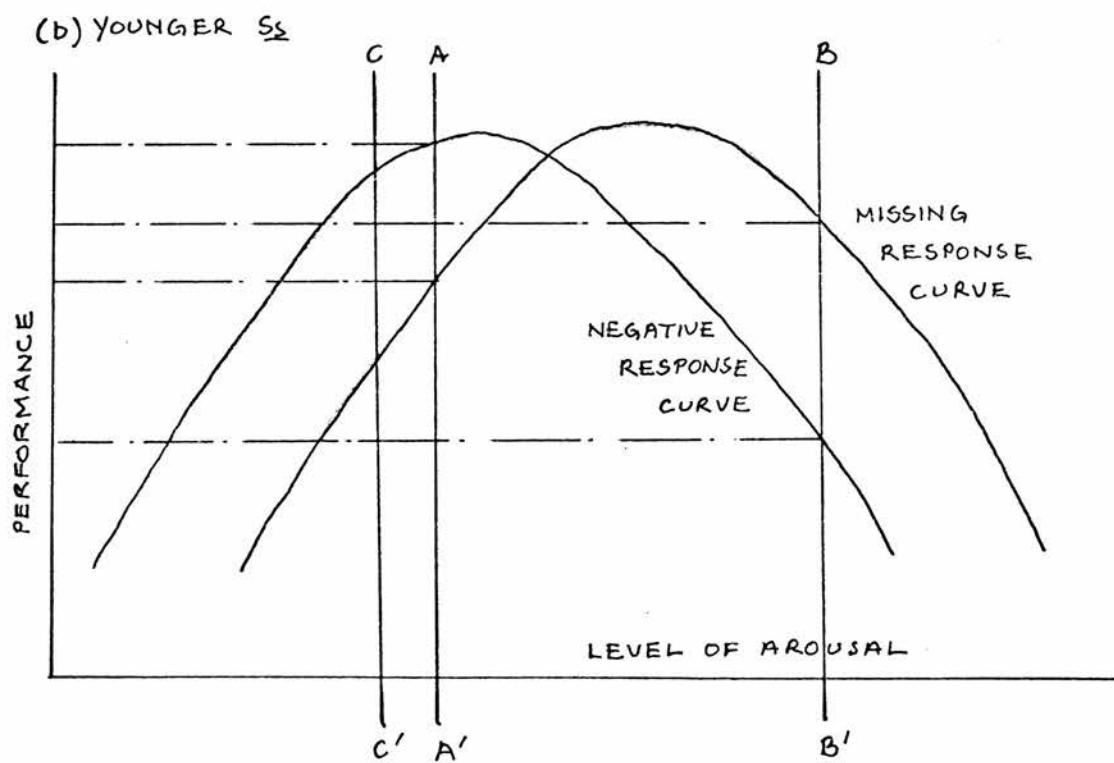
HYPOTHETICAL AROUSAL FUNCTIONS TO ACCOUNT FOR MAIN TRENDS
IN THE RESULTS OF EXPERIMENT 1
FIG. 18

then the data concerning the N-score would have permitted the conclusion that the predicted decline was a statistically significant one (see the data in Table 3).

Three limitations of the above account are as follows: First, it cannot account for the data concerning extra responses or the ratio of late responses. No significant differences in these response measures were detected between the various experimental conditions so this is perhaps no serious shortcoming. Second is the _prima facie_ problem that younger _Ss_ are supposed to be functioning at a higher level of arousal than older _Ss_ in the first (no-feedback) run, and yet they miss out more responses. The arousal theory may be able to reconcile these demands by stressing that whilst _changes_ in arousal produce _changes_ in performance, the level of arousal does not determine absolute levels of performance. Hence the initial level of 'noise' in the response system is an independent parameter. Third, and most important, is the fact that explanations in terms of hypothetical arousal functions are very weak unless some experimental measure of arousal is used to provide a constraint on the choice of theoretical curves used in the explanation. For a general discussion of such adequacy requirements see Broadbent (1963b) and Corcoran (1965). Despite these shortcomings the arousal theory shows more promise than one in terms of lack of proprioceptive feedback.

Conclusion

One of the proposed bases for understanding the regulatory function of language has now been subject to both a theoretical and experimental examination. The theoretical scrutiny suggested that it was not clear how the feedback result was in fact functioning as a model for Luria. Now it has been shown that the process is not, in any case, available in the required form to function as a model at all. However, the central requirement of the Vygotsky Condition has not been touched. This is the requirement that the speech system be superior to the motor system in its ability to organise and time responses. A direct examination of this claim will be the subject of the next experiment. Using the language of the Shunt Model the next experiment will ask whether the verbal system really can take a greater 'current' of excitation than the motor system.

EXPERIMENT 2. COMPARISON OF VERBAL AND MOTOR RESPONSES IN 4 AND 5 YEAR OLDS

In this section one of Luria's very basic claims will be examined. This is the claim that in young children the verbal system is superior to the motor system in terms of its ability to organise and time responses, say, to sequences of signals. The somewhat surprising nature of this claim should not be missed. Although the speech system and the motor system have, for the purposes of exposition, been treated as if they

are two different things, it is of course true that
speech can also be looked upon as a motor skill,
especially when used in the limited way that it is in
the Luria type of experiment.   In this case the claim
to be considered is that such a well practised activity
as grasping things is inferior to what is probably a
less well practised activity, viz. forming words.
Adding to the paradoxical nature of Luria's claim is the
well known fact that for adults the verbal R.T. is
longer than the motor R.T. (Wells, 1924) leading to the
suggestion (Woodworth, 1938) that verbal R.T.s may be
more complex (p. 329).   There is, however, a result
which seems to conform to Luria's requirements.
Alluisi, Muller and Pitts (1957) found that with the
forced-paced, serial presentation of arabic numerals,
number naming responses were more efficient than key-
pressing responses.   Indeed the rate of transmission of
information was some three times higher for the verbal
system.   But this does not necessarily establish the
superiority of the verbal system as such because the
well learned association between the stimulus and
response in the naming task could account for the result
(cf. Exp. 7 below).

As was stated earlier, the superiority of the
verbal system is a central requirement of any theory
which gives the verbal system the role of taking over
and improving motor performance.   This requirement was
termed the Vygotsky Condition.   Luria explicitly

recognises this condition, for he says, when applying
his ideas to the behaviour of cerebro-asthenic children,
'only when the neurodynamics of their verbal processes
prove to be more intact, shall we be able to utilise
these processes as a means of compensating for the
defects so clearly observed in the motor reactions'
(1961, pp. 76-7).

Describing an experiment on normal 3-4 year old
children Luria says that when they were asked to make
verbal responses to signals,

> they did not experience any appreciable diffi-
> culties in fulfilling the instruction to react
> to each signal with the words "Go!", "Go!".
> This task interested them greatly; their
> verbal reactions were always strictly co-
> ordinated with the signals, the latent periods
> being much more stable than those in the motor
> reactions. In contrast with the experiments
> demanding motor reactions, these experiments
> resulted in practically no perseverating
> verbal behaviour produced independently of the
> signal, nor on the other hand did the responses
> become extinct.

(Luria, 1961, p. 45)

The following empirical claims can be extracted
from this account:

(1) reaction times to verbal responses are more stable
   than to motor responses;

(2) there are fewer extra verbal responses than motor
   responses;

(3) there are fewer missing verbal responses than motor
   responses.

In the following experiment these claims will be
tested.   The experimental technique used will be very

similar to Exp. 1, where some signals require a response, and others the inhibition of a response. This will also make it clear whether verbal responses occur less often to what have been called negative stimuli than do motor responses. The claim that the proportion of late responses is less for verbal than for motor responses can also be tested. (These can be considered as numbers (4) and (5) to be added to the list of empirical claims given above.)

One reason for using the slightly more complex task of Exp. 1 - Luria's experiment just had positive signals - is that the mean age of the Ss will be slightly higher than Luria's. The reason for this was ease of availability. Limitations in the experiment because of this slight age difference will be dealt with in the discussion.

Hypothesis

The ability of young children to make verbal responses to sequences of blue light signals but not to interspersed yellow light signals is greater than the ability to perform the corresponding motor task where the response consists in pressing a small rubber bulb held in the hand. 'Greater ability' is defined in terms of fulfilling the five empirical claims listed above.

Subjects

The details of the Ss are given in Table 4 below.
The Ss were drawn from the Drummond Street School as in
the previous experiment.

TABLE 4

Details of the Subjects of Experiment 2

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Test Score*	S.D.
Younger Ss	16	52.5	4.9	47.7	6.5
Older Ss	16	70.2	6.7	53.1	4.2

* Raw Score.   See Appendix I.

Design

The experiment was designed to compare verbal with
motor responses on the same task.   Each S was used as
his own control and given two experimental runs, one
making verbal responses, one making motor responses.
Half of the Ss performed the motor task first, half the
verbal task.   Equal numbers of boys and girls were used,
the same number of each sex being assigned to each of
the two orders of presentation.   Two age groups were
used, with N = 16 for each age.   The task given to Ss
was the same as in the first experiment, except that in
one run the S is to utter the word 'go!' rather than
press the response bulb.

Apparatus

This was the same as in Exp. 1.   The stimulus values were also exactly the same as those used previously.   The only difference in the apparatus was that for the verbal trial the Ss held in their hand a small, light microphone into which they spoke.   This microphone produced a signal on the event recorder. Unlike the motor run a continuous trace rather than an on/off signal was used.

Scoring Criteria

The different categories of mistakes were the same as those used in Exp. 1.   The only significant difference in scoring in this experiment lies in the fact that for the verbal responses a decision had to be made as to when a trace indicated a signal and when it indicated mere background noise.   Such a decision is in the last resort arbitrary but it must be made consistently and objectively.   Examination of the various response traces led to a decision to count as a response any trace which was displaced from the midline by over two millimetres for a distance of up to or over five millimetres; given the speed at which the recording paper was passing through the recorder this corresponded to a time of one quarter of a second.   This criterion cut out the spiky traces which checks revealed were merely due to breathing, but it caught those occasional whispered responses whose traces were less obvious than

the traces of clearly spoken responses.

Procedure

This was very similar to Exp. 1.   Ss were trained
up to the same criterion as in the previous experiment,
given the first run, trained up to the same criterion
with the new response, then given the second experimental
run.   The only real difference, then, lay in the
training to make the verbal response.

In being introduced to the verbal response Ss were
first shown the little spot of light on the event
recorder.   (The apparatus in question was an A.E.I.
Oscillograph which recorded a trace on light sensitive
paper.)   They were shown how the spot shot back and
forth when E spoke loudly into the microphone, and how
it hardly moved at all when E whispered.   The micro-
phone was then handed to S who was told to say his name
loudly into the microphone and to repeat the numbers
1, 2, 3... whilst looking to see how the spot of light
moved.   The purpose of this was to give the S some
indication of what loudness of voice was wanted and give
him some incentive to speak in a normal speaking voice
rather than a whisper.   The S was told to speak so as
to make the spot move a lot.   It also helped Ss to be
aware of how to direct their voice into the microphone.
Pilot experiments without this special training
procedure had shown that Ss were prone both not to
speak into the microphone, perhaps letting it rest in

their lap, and, significantly, to let their verbal
response lapse into a whisper or even a mere mouthing
of the response word.   Having established the sort of
response wanted, the Ss practised with the response
'go!' in front of the stimulus screen with stimuli
being presented manually until they achieved the stated
criterion.   Here again great attention was paid to
encouraging Ss to maintain a speaking voice rather than
lapse into a whisper.

Results

The results will be analysed in the following order:
(i) missing responses, M, (ii) responses to negative
stimuli, N, (iii) proportion of late responses to late
plus correct responses, L/(L+C), (iv) extra responses, E,
(v) reaction times.   The study of reaction times will
involve a direct comparison of the mean lengths of motor
and verbal reactions and a comparison of their
'stability', or variability.

Missing Responses

The data concerning the mean number of missing
responses made in the different conditions for the two
age groups is given in Fig. 19.   Wilcoxon tests were
carried out to compare the verbal and motor performance
of all the younger Ss, then all the older Ss, then the
male and female subgroups at each age.   No significant
differences were found.   However, if all Ss, of both

ages, are grouped together a significant difference in the predicted direction is found between verbal and motor responses. ($z = 2.27$ $p < .012$ on a one-tailed Wilcoxon test, $N = 29$.) So, overall, verbal responses are better than motor responses with regard to the number of missing responses.

Negative Responses

Fig. 20 shows the overall performance with the two types of response for the two ages. Wilcoxon tests reveal no significant differences between verbal and motor responses for any of the groupings or breakdowns used in the section on missing responses. These same groupings and breakdowns of the Ss will be used in all the remaining response measures.

Proportion of Late Responses

Fig. 21 gives the overall performance for the two types of response at the two age groups. Wilcoxon tests reveal no significant differences between verbal and motor responses.

Extra Responses

Again no significant differences are to be found using Wilcoxon tests between the verbal and motor responses. Fig. 22 gives the overall performance levels at the different ages.
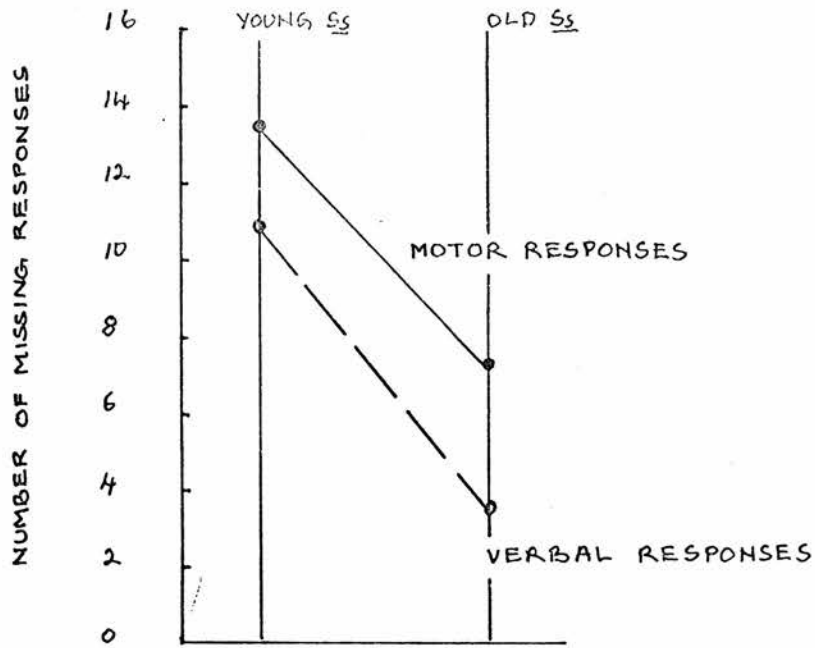
COMPARISON OF THE NUMBER OF
MISSING VERBAL AND MOTOR RESPONSES

FIG.19
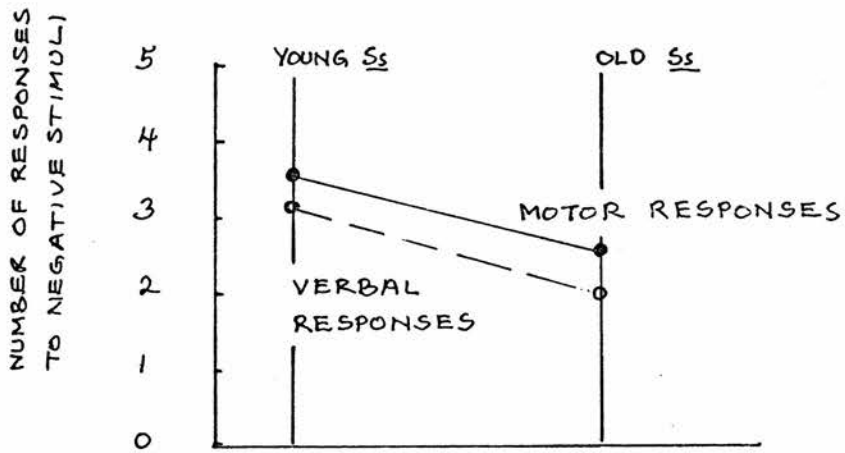
COMPARISON OF THE NUMBER OF VERBAL
AND MOTOR RESPONSES TO NEGATIVE
STIMULI

FIG.20
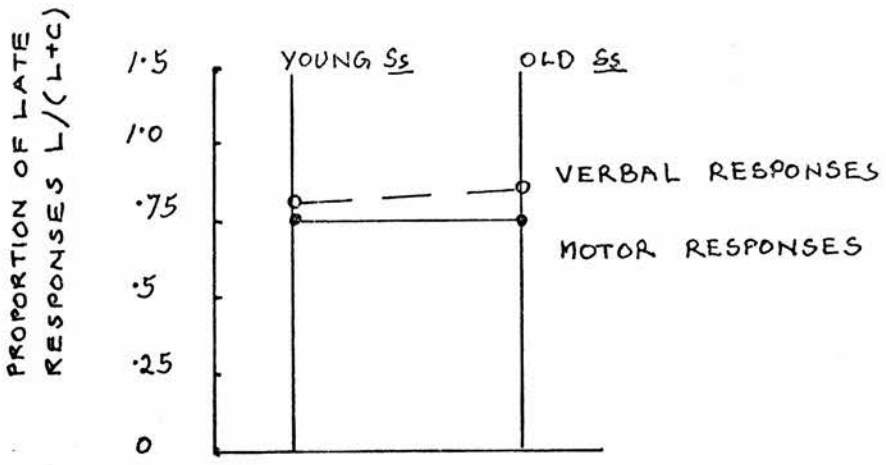
COMPARISON OF THE PROPORTION
OF LATE MOTOR AND VERBAL RESPONSES

FIG. 21
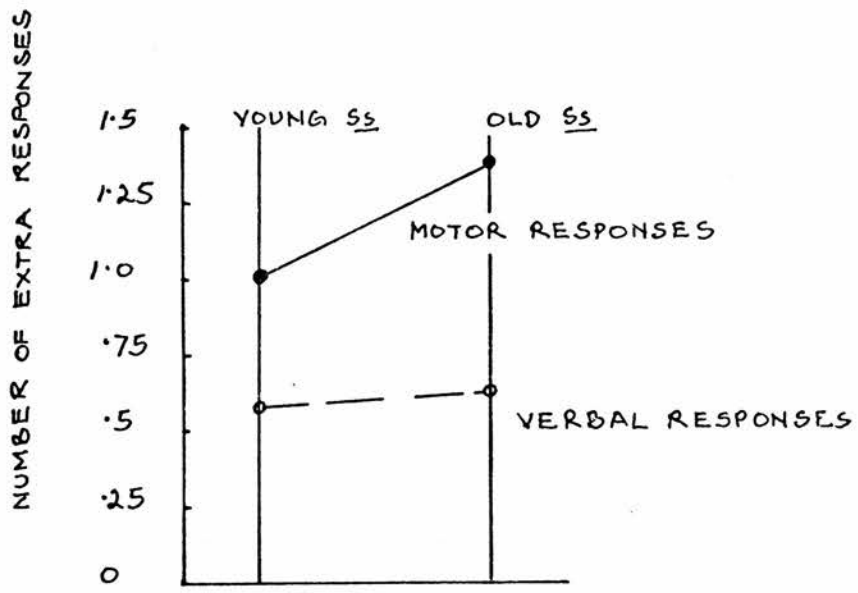
COMPARISON OF THE NUMBER OF
EXTRA MOTOR AND VERBAL RESPONSES

FIG. 22

Reaction Times

For each S two mean reaction times were calculated, one for the motor response, one for the verbal response. Wilcoxon tests show no significant difference between them (see Fig. 23). To compare the stability of responses, the range of reaction times for each of the two types of response was calculated for each S. The range equals the difference between the longest and the shortest reaction time. Again, Wilcoxon tests did not show any significant differences.

Discussion

The hypothesis of the superiority of verbal responses over motor responses is only very weakly supported. With one exception the results do not conform to Luria's hypothesis. Luria predicts that in a variety of respects timing, number of missing responses, number of extra responses, the verbal system should produce a superior performance to the motor system. In the present experiment this is not, in general, true. The one result which does conform to his prediction is that significantly less verbal than motor responses are missed, but although this effect is statistically significant it is not strong. The result, then, does not provide much evidence that the Vygotsky Condition is satisfied, as is required if language is to be given a regulatory function.

There is, however, a reason for thinking that the
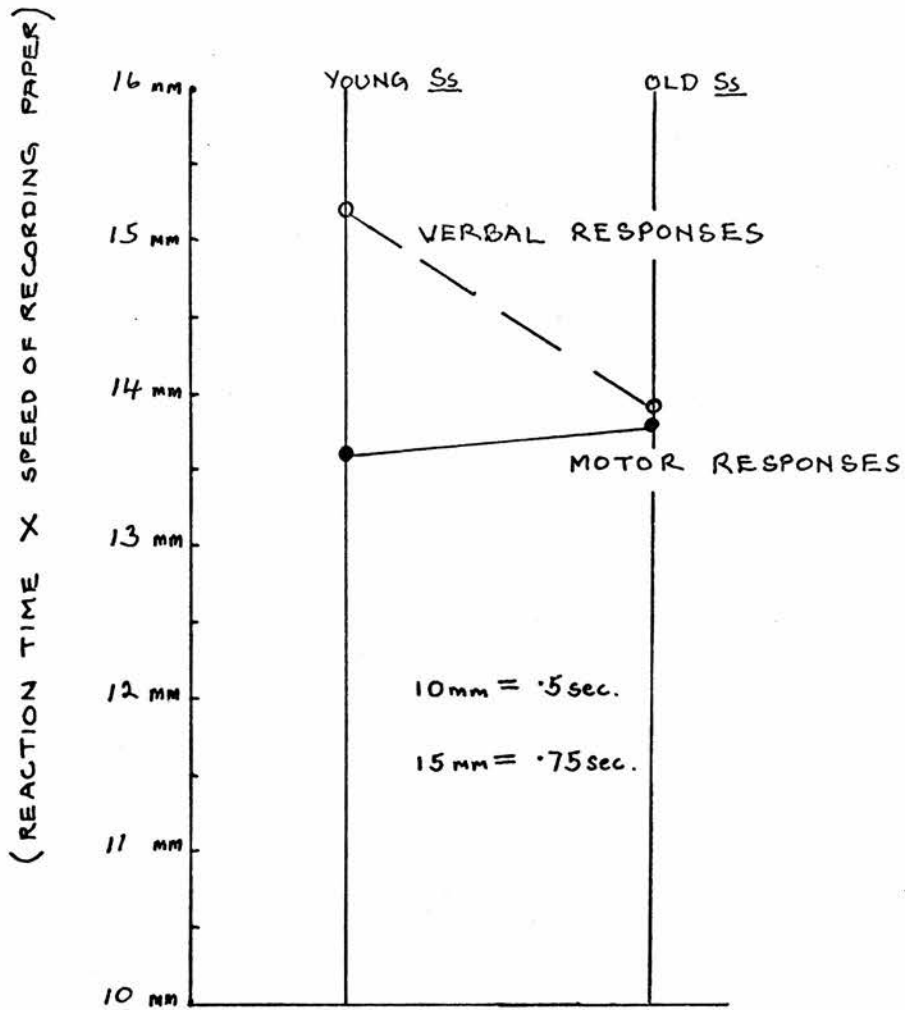
COMPARISON OF THE MEAN REACTION
TIMES OF THE MOTOR AND VERBAL RESPONSES

FIG. 23

significance of this experiment may be limited, because
the Ss (even in the younger group) are a little older
than the 3-4 year olds used by Luria. The argument
based on this fact is as follows: because of the age of
the Ss the motor responses (possibly with help from the
speech system) have already achieved a high level of
performance. Consequently the fact that the speech
responses are not noticeably better than the motor
responses is to be expected. Only if the motor system
is examined with younger Ss at a stage when it still
shows considerable deficits will the superiority of the
verbal system become apparent. The crucial tacit
premise of this argument is that both systems are
working at a level of near perfection. The very low
average number of extra and negative responses fits in
with this interpretation. The error score which shows
a large average number of mistakes is the M score for
missing responses: it is this score on which the verbal
system does show itself up to be superior to the motor
system.

In the light of this argument the result of the
experiment should perhaps be expressed by saying that on
the one response measure where the alleged superiority
of the verbal system might show itself, it did so. So
it is only with regard to the M score that this experi-
ment constitutes a genuine test of the hypothesis; and
the hypothesis passes the test.

The argument just examined suggests that Luria's

prediction has perhaps been as well verified as the circumstances of the experiment permit. This conclusion must be subject to two qualifications. The first has already been mentioned; it is that the superiority of the verbal system, as regards missing responses, though significant, is not marked. The second and related point is that according to the quotation given earlier from Luria the verbal responses of the 3-4 year old child were, apparently, almost faultless and there were 'no appreciable difficulties in fulfilling the instructions'. The results of this experiment, however, show that for the younger Ss there was an average of 10 missed verbal responses out of 30 possible. So one third of the required verbal responses were missed, even though the children were older than Luria's Ss. Here, then, the argument about the near perfection of performance reverses itself. According to Luria when the Ss were responding verbally their performance should have been nearly perfect, when in fact it was only about two thirds perfect. So even if it is granted that the verbal system is superior to the motor system, as Luria predicts, the absolute level of verbal performance falls considerably short of what Luria suggests, and to this extent falls short of the requirements of the Vygotsky Condition. In terms of the Shunt analogy this means that there does not seem to be much scope for the verbal system to prevent the motor system from becoming overloaded. It would be like

trying to protect a sensitive instrument in an
electrical circuit by a shunt that could not carry the
bulk of the current.

Conclusion

In outlining Luria's development of Vygotsky's
ideas a variety of theoretical levels of generality were
distinguished.   At the lowest level of generality were
the two different models which Luria has used to
explain in detail how/the verbal system regulates the motor
system.   The first of these models to be outlined, the
Feedback Model, has been tested in Exp. 1 and found
wanting.   The second model, dubbed the Shunt Model, is
a particular form of the Vygotsky Condition and has in
some measure been tested in Exp. 2.   This experiment
was not perfectly focused: the Ss were some 5 months
too old for it to be a direct test of Luria's claim
about the relative diffuseness of the verbal and motor
systems.   Despite this the experiment revealed a level
of inadequacy in the verbal system which does not
conform to the requirements or expectations of Luria's
account.

It would be exaggerating to say that the two models
at the base of the theoretical hierarchy have been
refuted by Exps. 1 and 2.   But these experiments
suggest that it might be more fruitful to pitch the rest
of the investigation at a slightly higher level of
generality;   that is, to focus on the general claim that

verbal processes are intimately involved in the organisa-
tion of motor responses in the form of self-instructions.

The general form of the thesis that language
regulates and organises ongoing motor behaviour will now
be constructed by quotations from Luria's work.   The
content of these propositions, along with deductions
drawn from them, will from now on be collectively
referred to as 'Luria's theory' or the 'regulatory
thesis'.   This general form of the regulatory theory
will be the subject of experimental test in subsequent
chapters.

The General Form of the Regulatory Theory

One major component in Luria's theoretical stand-
point is his belief that even the most simple responses
in the older child and adult bear the stamp of the
higher mental functions or intelligent thought.   In
taking this position he is reacting against a view of
human behaviour which sees its complex forms as a
mechanical accumulation of 'atoms' of simple reflexes.
Luria's is a dialectical view which allows the higher
mental functions to possess autonomous principles of
operation which then filter down and modify the workings
of the simpler processes.   This characteristic mode of
thinking is brought out in the following quotations:

> The reactive process of the human adult cannot
> be explained as a mechanical habit, it is
> constructed not only from below, but from
> above, it includes within itself the
> regulating systems of a higher psychological
> order.

(Luria, 1932, p. 395)

> The usual conception of the development of a
> child's motor skills as a gradual progression
> from the lower forms to the higher, gives way
> here to another...the processes which we
> consider simple depend upon much more
> complicated ones, including them as hidden
> mechanisms.
>
> (Ibid., p. 421)

> The internal structure of the simple reactions
> is thus a very complicated one and we should
> search for the specific mechanisms concealed
> within it and having to do with its regulation.
>
> (Ibid., p. 388)

The higher order processes which are concealed in the

structure of even very simple responses 'as hidden

mechanisms' are verbal in character.

> Precisely in the activity connected with
> speech we succeeded in observing the transfer
> from the primitive, diffuse and direct process
> to the process splitting into two functionally
> different phases - the phases of preparation
> and of execution. By virtue of speech, the
> primitive impulsiveness is overcome, and the
> direct attempts of adaptation are substituted
> by the preliminary connection in words; after
> this comes the motor execution.
>
> (Ibid., p. 389)

(For clarification of the idea of the two phases see

Fig. 2(b) where they are indicated.) On the basis of

clinical observation Luria adds to the above that:

> the limits of speech are not where we are
> accustomed to see them...numerous functions
> externally having nothing to do with speech
> are actually verbalised, and after impairment
> of the speech function, they drop out.
>
> (Ibid., p. 389)

Luria also outlines the general technique whereby

his theory could be tested and these will be briefly

given to show that the experimental approaches used in

later chapters are of the sort that the originator of

the theory would accept as legitimate tools for
investigating his ideas.   First of all he recommends
that highly practised tasks are not used because when a
task becomes automatic its structure will not be so
accessible;   like a tight knot its parts will be
inseparable (1932, p. 395).   Second is the suggestion
that the role of higher processes can be demonstrated
by observing the effect of weakening their relative
influence.

> We attain this by two simple methods: we may
> use the normal subject while in a condition of
> extreme fatigue, or we may divert the higher
> regulators from the reactive function, giving
> it another load, inducing the subject to
> change his attention.
>
> (Ibid., p. 384)
>
> Such a functional exclusion of the higher
> cortical mechanisms from participation of the
>   sic simple reactions evokes a return to the
> primitive, diffuse type of reactive processes....
>
> (Ibid., p. 385)

Finally a quotation will be given to provide a rationale
for the choice of age-group of Ss in the forthcoming
experiments.   What is required are Ss whose behaviour
will show (on Luria's theory) a considerable degree of
verbal involvement in the organisation of their motor
responses and yet who are not of such an age that the
verbal processes will have become so habitual that they
cannot be interfered with or dislodged.   The age
selected is around 75 to 80 months (except for a group
in the very next experiment where an extremely simple
task is used), so this takes the Ss comfortably within
the category required as judged by the following claim:

When a child develops normally, the closest
interaction of the two signal systems is
established as early as the age 5 or 6, and
under laboratory conditions, the abstracting
and generalising function of language begins
to play a decisive role in the development of
new connections.

(Luria, 1957, p. 124)

These quotations will have made concrete the form of
the theory which will be the object of scrutiny from now
on.   This general form of the theory carries at least a
suggestion that the thesis of verbal self-regulation
should now be interpreted as the slightly weaker claim
for the importance of verbal participation in the
organisation of motor responses.   In the light of Exp. 2
the greater independence of the theory from the demands
of the Vygotsky Condition is perhaps fortunate.   In
Chap. II some very simple forms of motor response will
be considered and their relation to the verbal system
investigated.   In Chaps. III and IV somewhat more
complicated and revealing tasks will be studied by the
techniques and approaches worked out in Chap. II.   In
the next chapter the beginnings will also be seen of an
alternative theory to the regulatory picture outlined
above;   this will have emerged fully by Chap. IV where
it will stand in full opposition to Luria's approach.

CHAPTER II

SOME SKINNERIAN WORK ON VERBAL SELF-REGULATION

There have been a number of studies in the Skinnerian
framework which bear on the general claim that language
has a regulatory function.   These studies have been
explicitly related to Luria's ideas by their authors.
The manner in which they have interpreted him make their
work an appropriate starting point for an investigation
into what has been called the general form of the
regulatory theory.   Two of these works will be reviewed
in detail, and, in the light of some methodological
criticisms the third and fourth experiments of this
study will be presented.

Review of Experiments

Lovaas (1964) investigated how the rate and content
of verbal operants can control operant manual responses.
His first experiment established that the rate of overt,
repeated counting of the numbers 1 to 5 influenced the
rate at which a lever was pressed.   Four $\underline{Ss}$ (4-5 - 5-2)
were trained to count rapidly to one colour of light and
slowly to another colour.   They were then told to press
a lever up and down whilst counting.   The $\underline{Ss}$ were not
told to press either rapidly or slowly.   The lights
were presented randomly over a period of five minutes,
at 10 sec. intervals, each light flash lasting 20 secs.
$\underline{Ss}$ received rewards of tokens (to be exchanged for toys)

on a fixed interval 10 sec. schedule, provided that
they were counting.

The next experiment showed that under similar
conditions certain Ss would spontaneously repeat the
word 'faster' at a greater rate than the word 'slower'.
This shows that the content of a verbal operant can
affect its rate of production.   Of the ten Ss
completing this experiment this conclusion applied to
the six older children (5-2 - 7-4).   One child (5-1)
showed the reverse effect and the three younger children
(4-9 - 4-10) showed no significant difference in speed
of production.   The mechanical difficulties of word
production could not account for the result because the
available data (cited by Lovaas) would produce the
opposite prediction.

Lovaas' third experiment studied the effect of the
content of a verbal operant on the latency of a non-
verbal operant.   The Ss (three groups of 7 children
aged 6, 9 and 11 yrs.) were trained to respond with the
word 'faster' to one light and the word 'slower' to
another light, until the discrimination was firmly
established.   The latencies of a lever pressing
response under alternate presentation of the lights were
then observed.   There was a 5 sec. interval between
light presentations, and each signal was terminated by
the lever press.   Ss were rewarded every $\frac{1}{20}$th of a
second for light-off periods.   The latencies for the
'faster' light were significantly shorter than latencies

for the 'slower' light.   There were also significant
differences between the age groups.   The mean
differences between the latencies for the fast and slow
lights increased with the age group of the Ss.

Lovaas also discusses two further experiments not
reported in detail.   One of these will be noted here
because of its bearing on the forthcoming experiments.
Lovaas investigated whether the rate of a non-verbal,
lever pressing task could be controlled by the content
of a verbal response of 'fast' or 'slow'.   In previous
training the words had been associated with different
stimulus lights and these were then presented alternately.
With 5 and 6 yr. olds Lovaas says that, "only sporadic
and weak control was observed over the manual operants".
Pre-training altered the situation markedly, because,
"where S's manual responding was first brought under the
control of A's [adult's] verbal behaviour, then S's own
verbal behaviour would control his own manual
responding".   Some comments will shortly be made about
this experiment.

Meichenbaum and Goodman (1969) cite Lovaas' work
(along with Bem (1967) and Birch (1966)) as contributing
to Luria's picture of the developmental growth of the
verbal system as a regulator of the motor system.
Their experiment examined the "relative efficacy of the
differential modes of delivery of verbalisations in
governing non-verbal behavior".   They used a task
similar to Lovaas' in which a child is instructed to tap

whilst the words 'faster' and 'slower' are repeatedly verbalised: (1) by E; (2) by S, aloud; (3) by S, whispering. The amount of verbal control of behaviour, they argued, is indicated by the degree of change in the rate of tapping.

After being divided into three groups corresponding to the three modes of presentation of the verbal command the Ss were given six different tasks, with two 15 sec. runs per task. First there was an operant (baseline) task in which Ss were just told to tap without any speed being specified. Second there was a tapping task in which the word 'letter' was uttered. Third and fourth came the 'faster' and 'slower' tasks, whose order was counterbalanced. Fifth came another 'letter' task, and finally another purely operant task. In the 'faster' and 'slower' phases of the experiment, and in all three experimental conditions the Ss were instructed to "tap the way the word means".

The results showed that the mode of delivery of the verbalisation is an important variable. For example, for first graders (6-7 yr. olds) the increase in the rate of tapping "was equally effected when the verbalisation 'faster' was externally or covertly administered, and had least functional significance when the self-verbalisation was overt" ('external' refers to E's delivery of the verbal response). For kindergarten children (5-6 yr. olds) the external and overt conditions had equal control over tapping speeds, the

covert conditions least.   The same is true for the
'slower' task when allowance is made for the fact that
$\underline{Ss}$ respond using the previous level of performance
(either 'letter' or 'faster') as a base line.

These experiments establish some basic results
regarding the regulatory function of language.   They
also raise some important methodological issues
concerning experimental method, theory and presentation
of results.   These will now be examined.

Methodological Comments

First some observations on Lovaas' paper.   Certain
crucial facts about the experimental situation are
missing from the paper so that its full significance
cannot be assessed.   That the facts in question are
missing is not a mere shortcoming of the presentation.
It seems to result more from the way the experiments
have been conceptualised in the first place.

In Lovaas' first experiment the $\underline{Ss}$ had to count
rapidly or slowly and at the same time press a lever.
They pressed rapidly when they counted rapidly and vice
versa.   Might the children have thought that they had
been asked to press the lever rapidly when they counted
rapidly?   The experimenter carefully refrained from
specifying how the child should press the bar hoping
that from this deliberately manufactured lacuna in the
situation a clear link between language and action would
emerge.   The experiment depends on this gap; but what

if there is no gap as far as the child is concerned?
The possibility that the child has filled in this gap by
assumption cannot be lightly dismissed.   Lovaas
unwittingly provides evidence on this question.   He
reports that the children offered elaborate hunches about
the purpose of the experiment and evinced complex beliefs
about the events in the experimental situation (e.g. "odd
numbers always seemed to go with the blue light except
after the marbles", the marbles being used for rewards).
That a deliberately produced gap in the Ss' understanding
should be filled with plausible assumption is thus quite
possible.   (This criticism is a generalisation of
Bartlett's (1932) criticism of Ebbinghaus.   The basic
point is that the complexity of a response is a function
of the complexity of the responding organism rather than
of the simplicity of the stimulus situation as judged by
some arbitrary criterion.)   The methodological moral
for child psychology is that the experimental situation
should not be under-determined lest uncontrolled factors
intrude as a result of the child's assumptions and
beliefs.

A related problem lingers around Lovaas' account of
the influence of the content of a verbal operant on the
rate of lever pressing.   Lovaas says that without
pre-training, "At best, only sporadic and weak control
was observed over the manual operants."   It is not clear
what this means.   One hypothesis as to what it means,
for which there is no counter-evidence in Lovaas' paper,

is that because the S̲s̲ had not even been told that they
were expected to press the lever, let alone press it in
any given way, then they naturally did not do so.
What was the S̲ given to understand about what others
expected of him?   This crucial information is missing.
In its place there is a sentence whose meaning is un-
clear.   The same applies to the account of the pre-
training which did result in lever pressing.   What is
it to bring "S̲s̲ manual responding under the control of
A̲'s [adult's] verbal behaviour"?   Did the adult t̲e̲l̲l̲
the child to press rapidly when saying 'fast'?   The
whole of this objection can be expressed by saying that
the experimental account is 'theory-laden'.   An
operational definition is required of the terms used, or
else an adequate explanation in terms of familiar,
everyday concepts.   This second criticism relates to
the first criticism, regarding gaps in the instructions,
because adopting the technical vocabulary of some
theoretical standpoint carries the danger that its users
will simply overlook the necessity to clarify issues, or
guard against dangers, that are significant from the
standpoint of either common sense or other theories.

An objection to the second of the above criticisms
is that it applies to an experiment that was only
briefly discussed and consequently to a result that is
unlikely to be perpetuated in the literature.   In reply
it need only be pointed out that Meichenbaum and Goodman
cite the result of Lovaas' that is in question without

regard to the obscurity of the presentation.   Indeed

they use the same opaque phrasing as Lovaas.

A similar criticism, regarding the theory-laden
nature of the reporting of results, can also be made out
against Meichenbaum and Goodman.   In this case it does
not obscure the experimental results, but it does
obscure their possible significance.   Consider their
sentence, "An interesting finding was that for first
graders overt self-verbalisations had less functional
control over motor behavior than covert self-verbalisa-
tions" (p. 564).   This sentence, though a true report
of their findings, gives the impression that overt self-
verbalisation still has some 'functional control over
motor behaviour' for first graders.   In fact the
relevant graph in the paper (Fig. 2) reveals that the
mean number of taps accompanied by overt uttering of the
word 'faster' is less than the mean number of taps on
the first run, that are not accompanied by any verbalisa-
tion.   The terminology of 'functional control' is
obviously being strained, and its tenacity seems to be
preventing the radical alternative formulation of the
result: namely, that, far from exerting control, the
overt verbal responses are simply interfering with the
motor responses.

It is revealing to adopt this alternative stand-
point in a completely general way when looking at
Meichenbaum and Goodman's results.   This standpoint
highlights the fact that because the Ss were told to

press the key "the way the word means", what was being tested was the Ss' ability to obey instructions in a tapping task whilst at the same time performing another task of verbalisation or listening.   This formulation of the experiment makes no mention of control or regulation.   The results then show that for first graders overt verbalisation interfered most with the task of rapid tapping whereas with kindergarten children whispering interfered most.

This 'mirror-image' formulation thus leads to a theory of 'load' rather than a theory of 'regulation'. It suggests experiments in which the emphasis is on the different loadings imposed on the Ss by having to perform either overt or covert verbal tasks at the same time as motor tasks.   From this perspective the regulatory function of language as it occurs in Meichenbaum and Goodman's experiment appears to be an artefact of the experimental situation.   This possibility is disguised by the use of theory-laden terminology in the description of the experimental results.

In the light of these methodological comments the next experiments will be presented.   Particularly important are the issues raised by the alternative way of formulating Meichenbaum and Goodman's results.   This will be the subject of Exp. 3.

EXPERIMENT 3.   COMPARATIVE LOAD OF OVERT AND COVERT
VERBAL RESPONSES

The purpose of this experiment is to shed light on
the possibility raised in the methodological discussion
above, that both overt and covert self-instructions
constitute an extra load on the nervous system.   This
should result in the worsening of the performance of a
motor task to be produced simultaneously.   An oppor-
tunity is also provided to test the hypothesis that the
loading imposed by overt and covert verbal responses is
differently distributed at different ages.   This is the
'mirror-image' formulation of Meichenbaum and Goodman's
hypothesis concerning the developmental relation between
the regulatory power of overt and covert responses.
The basis of the experiment is to measure the decline in
the rate at which Ss tap as rapidly as they can when the
motor task is conjoined with overt and covert self-
instructions.

Hypotheses

Two hypotheses were tested:

(1)   Overt and covert self-instructions will both
interfere with the simultaneous performance of a motor
task.

(2)   For nursery children covert self-instructions
will interfere more with a motor task than overt self-
instructions.   For infant school children overt self-
instructions will interfere more than covert self-
instructions.

Subjects

The 32 Ss were drawn from the nursery and infants'
classes of the Infirmary Street Primary School, Edin-
burgh.   All Ss were free from sensory-motor defects.
All children from the infants' classes used participated
in this experiment or the next, so that there was no
selective process used by either the teacher or E.   No
selection process needed to be used in the case of the
nursery children either, because all of the children
were approached to take part.   Three of the children
refused to accompany E to the experimental room.   Of
the 16 nursery children who initially took part in the
experiment three female Ss declined to complete the
task: this accounts for the discrepancy between the
final number of Ss in the two age groups.   Mention
will be made of these three refusals below.   Table 5
gives details of the Ss.

TABLE 5

Details of the Subjects of Experiment 3

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Test Score[*]	S.D.
Nursery	13 (8 m, 5 f)	52	7.6	50	13.0
Infants	16 (8 m, 8 f)	75	7.4	56	7.2

[*] Raw Score.   See Appendix I.

Apparatus

The apparatus consisted of a morse key clamped to a table. The key was connected to a small, electrically operated, cumulative counter. The counter could be re-set manually. Each depression of the key was registered on the counter.

Experimental Design

After preliminary training each $\underline{S}$ was given four experimental runs lasting 15 secs. each. The first and last runs were measures of how fast the $\underline{Ss}$ could tap a morse key under the instructions to tap as fast as they could. The second and third runs were measures of how fast the $\underline{Ss}$ could tap the key (1) whilst at the same time repeating aloud the word 'fast', (2) whilst whispering repeatedly the same word. The order of the overt and covert runs was counterbalanced across $\underline{Ss}$.

Let the mean score on the non-verbal runs be called 'F', and the verbal component of the response be signified by the subscript 'f' (short for the word 'fast'), and the overt or covert mode by the prefix 'o' or 'c'. The scores on the experimental runs can then be represented by F, $_oF_f$ and $_cF_f$ respectively. Abstractly stated the hypotheses then become,

(1) $F > {}_oF_f$ and $F > {}_cF_f$ for both groups

(2) $_oF_f > {}_cF_f$ for nursery children

$_cF_f > {}_oF_f$ for infant children

Procedure

Ss were approached through the teacher or nursery supervisor.   They were told that E had a simple game that they might like to play.   Ss accompanied E to an adjacent empty classroom where they were shown the morse key.   They were told that it was a 'tapper' which was to be tapped up and down like this ... (E demonstrated). It was pointed out that every tap was counted on the counter.   S was then invited to try and shown how each of his taps was counted, and was then asked to try to tap fast.   Encouragement was given and S urged to tap even faster: 'tap as fast as you can go.'   When S appeared to be trying to tap as fast as he or she could the practice runs were terminated and the experimental runs started.

E held a stopwatch in his hand and told S that he (E) would say 'go' and then S was to tap as fast as he could, and keep on tapping, until E said 'stop!'   E then said 'go' and did not say anything further until stopping the run.   During the run E deliberately did not look at S so as not to distract him.   Throughout the run E was seated next to S who was seated before the morse key.

After noting the number of taps and resetting the counter, S was told that he had done well, and the second task was explained.   S was told that he was again to tap as fast as he could but was also to say, 'in a nice loud voice so that I can hear you, the words

"fast, fast, fast..." over and over again, all the time
that you are tapping'. E then gave a brief demonstra-
tion (in the demonstrations the word 'fast' was uttered
at the rate of about 4 per sec., the tapping was faster,
about 5 taps per sec., no attempt being made to produce
one word per tap). The appropriate variations in the
instructions were made for the covert run. The
performance of whispering was presented by E in his
demonstration to Ss as being the mouthing of the word
with a just audible sound. A short practice run of
about six taps and three or four verbal responses was
conducted to ensure that Ss were vocalising or
whispering properly. (It was when the nursery children
were asked to vocalise that the three Ss mentioned above
declined to go on with the experiment. A number of Ss
were inclined to speak very softly in the practice run
for the overt responses and in such cases the run was
repeated to ensure an adequate separation between overt
and covert responses. No S who continued with the
experiment required more than two brief practice runs,
and none had to be rejected because of a lapse into
whispering during the experimental run.)

Three further observations about the procedure may
be made. First, after Ss had had the various tasks
explained to them, the instructions were always repeated
immediately before saying 'go'. This ensured that both
experimental requirements, of tapping as fast as
possible and repeating the word, were prominently before

their minds.   Second, a number of the younger S̲s̲

occasionally made false starts; they would start tapping

before E̲ said 'go'.   Such runs were not, of course,

continued.   S̲ was stopped and gently reminded that he

must wait for the word 'go'.   Third, some S̲s̲ were prone

to interpret the request for rapid tapping as a request

for forceful tapping, banging the morse key with the

palms of their hands.   This tendency was eliminated

during training, all S̲s̲ learning to hold the key while

tapping.

A few days after the experiment had been performed

all of the S̲s̲ were given a modified form of the Peabody

Test (see Appendix I).

Results

First of all the results of the older, infant group

will be examined, and then those of the younger, nursery

group.   Third, the relation between these findings will

be examined.   In all cases the results of the male and

female S̲s̲ will be grouped together as there are no

significant differences between them.

Infant School Group

1.   Non-verbal and overt scores.

$F > {}_oF_f$, for every S̲.

2.   Non-verbal and covert scores.

$F > {}_cF_f$, significant at the .005 level, on a one-

tailed Wilcoxon test (T = 8, N = 15, where N is the

number of pairs of scores whose difference is non-
zero).

3. Covert and overt scores.

$_c F_f$ is <u>not</u> significantly greater than $_o F_f$ at the
.05 level on a one-tailed test (T = 38, N = 16,
using the approximation recommended by Siegel
(1956, p. 79), this gives z = -1.55, p $<$ .06).

Nursery School Group

1. Non-verbal and overt scores.

$F >_o F_f$, significant at the .005 level on a one-
tailed test (T = 1, N = 11).

2. Non-verbal and covert scores.

$F >_c F_f$, for every $\underline{S}$.

3. Covert and overt scores.

$_o F_f$ is <u>not</u> significantly greater than $_c F_f$ at the
.05 level on a one-tailed test (T = 38.5, N = 12,
giving z = .04, p $<$ .48).

Nursery and Infant Groups Compared

1. Non-verbal score.

The F scores for the two groups are significantly
different for the two groups at the .05 level on a
two-tailed test (U = 54.5, n1 = 13, n2 = 16, on a
Mann-Whitney test).

None of the remaining scores shows any significant
difference between the age groups at the .05 level on
two-tailed tests.   The calculated value of U in each

case (with $n1 = 13$ and $n2 = 16$) is: (2) overt score,
$U = 73$, (3) covert score, $U = 66$, (4) difference between
non-verbal and overt score, $U = 78$, (5) difference
between non-verbal and covert score, $U = 88.5$.

The mean values of the F, $_oF_f$ and $_cF_f$ scores is
shown in Fig. 24.

Discussion

Hypothesis 1 is strongly confirmed. Both overt
and covert self-instructions interfere with the
simultaneous conduct of a motor task. This strongly
suggests that Meichenbaum and Goodman's results do not
really demonstrate the regulatory function of language
at all, except in the trivial sense of showing that Ss
can obey verbal instructions to tap rapidly. The
reason why their Ss were/able to tap more rapidly whilst
uttering the word 'fast', than when not, was simply
because the base line performances did not demand of the
Ss that they tap rapidly.

Hypothesis 2 is only extremely weakly supported by
the data. There is no significant difference for
either age group between the overt and covert conditions.
In the older children, however, there is a non-significant
trend in the direction of covert responses being
accompanied by faster tapping than overt responses.
This is shown by the slightly higher mean value of the
scores to be seen in Fig. 24. But the differences
between the overt and covert conditions are very small
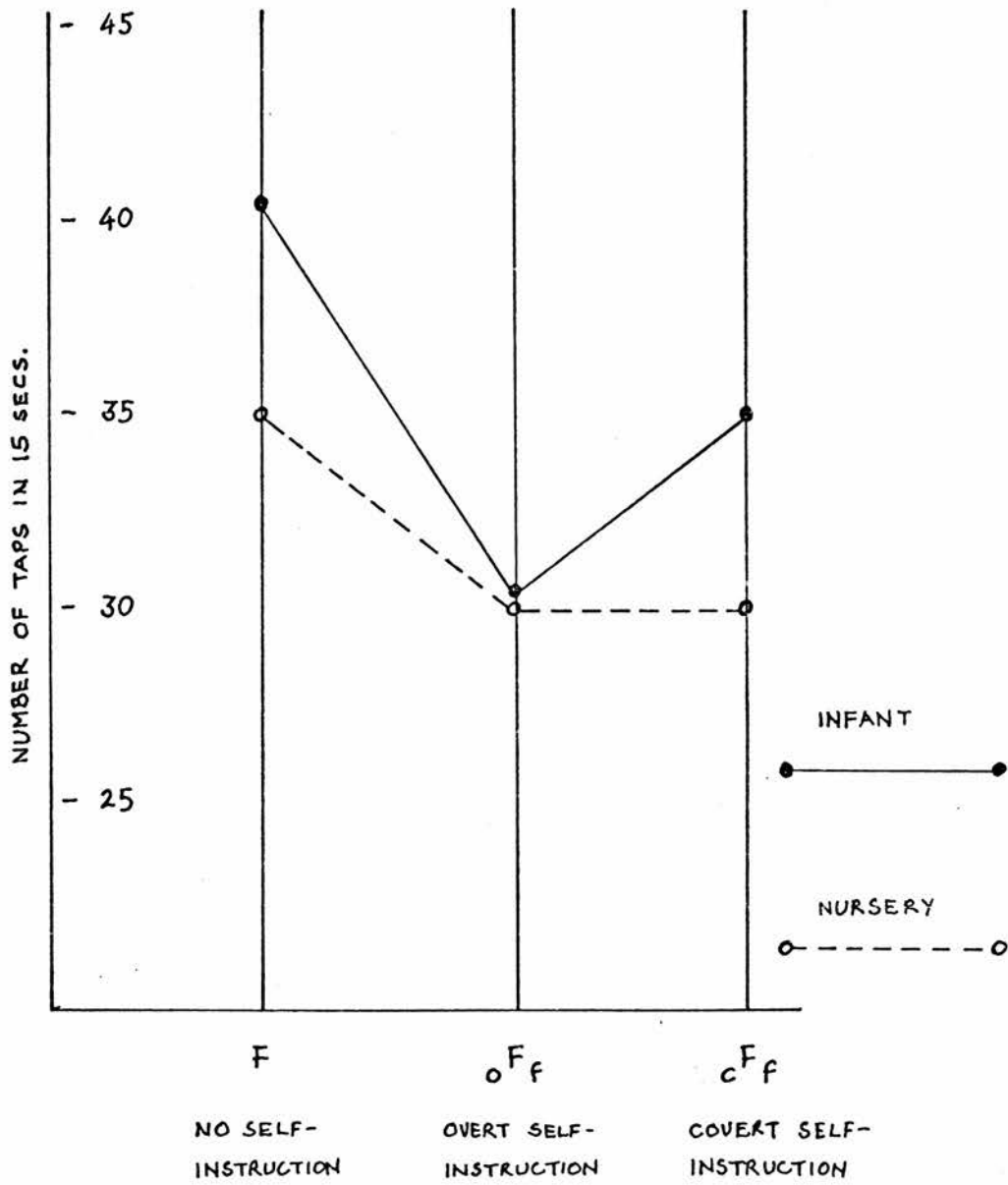
MEAN SCORES ON THE MOTOR TASK OF EXPERIMENT 3

FIG. 24

compared with the highly significant differences between either of them and the non-verbal score.

The outcome of Exp. 3, then, does not support the picture of language as a regulator of behaviour. Self-instruction in the task used in the experiment is not even compatible with the maintenance of the same level of performance as when the self-instructions are absent. The relation between the verbal and the motor system that seems most prominent is simply that the verbal responses impose a load on the motor system; in other words they are both competing for the same limited channel capacity. The experiment does not, however, show any significant difference between the overt and covert conditions in the capacity requirements of the verbal responses and so does not provide evidence for the full alternative interpretations of Meichenbaum and Goodman's results which was proposed in the previous discussion.

The objection may be raised, in defence of the regulatory function of language, that it was a foregone conclusion that the motor task would suffer from the extra loading of a simultaneous verbal task. These circumstances, it may be argued, are not appropriate for the regulatory aspects of language to show themselves. What is necessary is to compare the different loadings of self-instructions which are consonant and compatible with the ongoing motor task with the loadings of self-instructions which are incompatible with it. In

particular this may be investigated in circumstances
where Ss are not required to perform a motor task whose
proper execution would require all available capacity.

This objection brings out the limitations of Exp. 3.
The real significance of language as a factor in the
organisation of ongoing motor behaviour may only become
apparent when a motor set and a verbal task are pitched
directly against one another.   Second, Exp. 3 only
investigated one end of the spectrum of possible
performances of the tapping task.   It is not yet known
how language would interact with a motor set to tap
slowly.   In particular it is not known whether
differences between overt and covert verbal responses
would manifest themselves at the slow end of the
spectrum even though they were not significant at the
fast end.   These issues will be investigated in the
next experiment, Exp. 4.   (In the statement of the
underlying ideas and hypotheses of the next experiment
the results of Exp. 3 will be temporarily set aside so
that the issues can be stated in a general and unquali-
fied form.   The results of the two experiments will
then be drawn together and incorporated in the
discussion section.)

The next experiment will also provide an opportunity
to investigate further the idea that overt and covert
responses impose different loads on the motor system.

EXPERIMENT 4.   VERBAL SELF-INSTRUCTIONS VERSUS A MOTOR SET

The purpose of the experiment was to examine the role of <u>countermands</u> on a motor set.   A countermand is an instruction which runs counter to an ongoing motor task.   An example would be saying the words, 'slowly, slowly,...' when one has a set to press a key rapidly. If language has a directive or regulatory function (ignoring for a moment the results of Exp. 3), then a set to tap rapidly (or slowly) would be interfered with by repeated verbalisation of the countermand 'slow' (or 'fast').   Conversely the set would be augmented, or at least maintained, by a self-instruction compatible with the motor set.   Three hypotheses will be stated;   to preserve symmetry of statement the results of Exp. 3 will not be incorporated into their formulation.

Hypotheses

(1) In a key tapping task repeating the word 'fast' will augment a motor set to tap rapidly and undermine the motor set to tap slowly.   Conversely, repeating the word 'slow' will augment the motor set to tap slowly and undermine the motor set to tap rapidly.

(2) In infant school children whispering the self-commands or countermands will augment or undermine the motor performance more strongly than overtly spoken self-instructions (Meichenbaum and Goodman's claim).

On the other hand, from the point of view of the

alternative perspective outlined above the expectation would be that:

(3) Overt verbal tasks performed alongside a motor task will impose a greater load then covert verbal tasks.

No hypotheses will be proposed concerning the number of verbal responses made nor about the relationship of this number to the number of motor responses. The data will be examined to see what relationships emerge empirically.

A more rigorous statement of the hypotheses will be given below. This experiment unambiguously defines for the Ss the motor set that they are to adopt. The strength of the regulatory function of language is tested by seeing if it can overcome this set.

Subjects

The 48 Ss (24 boys, 24 girls) were from the Infirmary Street Primary School and the Milton House Primary School, Canongate, Edinburgh. The Ss were divided into two groups, an Overt group and a Covert group. (The whole of the first group came from the first of the above schools mentioned, but both were similar in atmosphere, classroom regime, and the social composition of their catchment areas.) There were equal numbers of each sex in each group. Table 6 gives the details of the two groups of Ss. No S had to be eliminated from the experiment because of sensory-motor defects or because of unwillingness to cooperate.

Experimental S̲s̲ were confined to those of an infant
school age because pilot experiments had shown that it
was very difficult, given the required experimental
design, to get nursery children to complete the
necessary number of experimental runs.

TABLE 6

Details of the Subjects of Experiment 4

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Test Score**	S.D.
Overt	24*	77.5	9.1	56.1	7.0
Covert	24*	76.5	6.3	59.6	9.5

    * Equal numbers of boys and girls.

    ** Raw Score. See Appendix I.

Apparatus

The apparatus consisted of a morse key clamped to a
small table, and a very light, hand-held microphone.
Both of these were connected to an oscillograph which
recorded each press of the key on one channel and a
trace of the spoken input to the microphone on the other
channel. For the Covert group, where recording the
verbal component of the responses was not feasible, the
oscillograph was replaced by the cumulative counter used
in the previous experiment.

Experimental Design

Each $\underline{S}$ was given two test runs of the tapping task with no verbal responses accompanying them. These were to provide a base line for fast and slow tapping rates. The test runs were always given in the same order (fast and then slow) and then four experimental runs were given. In the experimental runs the $\underline{Ss}$ were placed in turn in each of the following four conditions:

(1) Set to tap rapidly and repeat the word 'fast' (let F_f represent the number of taps produced in this condition).

(2) Set to tap slowly and repeat 'slow' (S_s).

(3) Set to tap rapidly and repeat 'slow' (F_s).

(4) Set to tap slowly and repeat 'fast' (S_f).

Since the above design applies both to the Overt and the Covert group the prefixes 'o' and 'c' have been left out of the symbols; they will only be inserted when it is necessary to differentiate between the two groups. It will be seen that two of the conditions (F_f and S_s), are command conditions, and two (F_s and S_f), are countermand conditions. The order of the experimental runs was randomised throughout the 24 $\underline{Ss}$ of each of the two groups, so that every possible order was used within each of the groups.

Given the symbols introduced above, and calling the scores of the test runs F and S, the hypotheses can be given a more formal but more thorough statement.

(1) $F_f > F^* > F_s$ and $S_f > S > S_s$ for both 'o' and 'c'.

A closely related formulation would be,

$(F_f - S_s) > (F - S)^* > (F_s - S_f)$ for both 'o'
and 'c'.

(2) $(_cF_f - _cF_s) > (_oF_f - _oF_s)$, $(_cF_s - _cS_f) < (_oF_s - _oS_f)$

$(_cS_f - _cS_s) > (_oS_f - _oS_s)$, $(_cF_f - _cS_s) > (_oF_f - _oS_s)$

(3) $(F - _oF_f) > (F - _cF_f)$

$(F - _oF_s) > (F - _cF_s)$

Procedure

$\underline{Ss}$ were approached on the same basis as Exp. 3 and
introduced to the apparatus in the same way. $\underline{E}$
explained that sometimes they would be asked to tap
very fast, like this ..., and sometimes very slowly
like this ....   In this demonstration the fast tapping
was at the rate of about 5 taps per sec. and the slow
tapping at the rate of about 1 tap per sec. $\underline{Ss}$ were
then asked to try tapping fast, and then, after a few
taps to try tapping slowly.   This was to ensure that
$\underline{Ss}$ could discriminate properly between fast and slow
responses.   If there did not appear to be an obvious
difference in $\underline{Ss}$' rate of tapping in these two tasks
they were asked to try again, this time trying to go
very fast, and very slow.   Very few $\underline{Ss}$ required this

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* From Exp. 3 it is known that $F > F_f$, $F > F_s$, etc.
This is being ignored at the moment for simplicity.

extra phase of training.   No Ss required more than one
such extra attempt.   When the discrimination had been
properly exhibited E explained that he would say 'go'
and Ss must tap fast and keep on tapping until he said
'stop' (this was the first test run, F).

On saying 'go', E pressed the start button of the
oscillograph and also started a stopwatch.   Just prior
to saying 'go', E said 'Remember to tap tast'.   No more
instruction or encouragement was given by E during the
15 sec. run.   As in the previous experiment E did not
look at S during any of the runs, but looked at the
stopwatch.   Each run was terminated by 'stop', and the
recorder stopped.   S was then told, 'Good, you did that
nicely', or some other short, generalised indication of
approval.

After the second test run, (S), S was shown the
microphone and told that it was for talking into.
(This part of the procedure obviously only applies to
the Overt group.)   Ss were then offered the microphone,
the offer being directed at the hand that Ss had not
selected for the tapping task.   They were then told
that this time they were to press the key fast (or slow
depending on the order of experimental runs to which
that had been pre-assigned) and at the same time they
were to say, 'fast' (or 'slow') 'in a nice loud voice,
over and over again, all the time you are tapping'.
E gave a brief demonstration as in Exp. 3.   The
instruction was repeated and Ss were asked if they

understood.   If they hesitated in giving an affirmative
reply, or if they looked puzzled or said that they did
not understand, the instructions were repeated.   This
was only necessary about half a dozen times throughout
the whole experiment.   Given a positive reply E would
say, 'Get ready and start when I say go, remember tap
fast, and say slow, ... go'.   Ss were then taken
through the remaining conditions, the task in each case
being explained immediately prior to the performance of
the task.   No demonstration was given before subsequent
runs.   The gap between each experimental run was about
30 secs.   Ss were then thanked and taken back to the
classroom after the apparatus had been made ready for
the next S.   (Only one S confused what she had to say
with what she had to do.   She was replaced by another
female S and is thus not counted amongst the 24 Ss of
the Overt group.   No S had to be discounted through a
reluctance to adopt a normal speaking voice rather than
a whisper, or for failing to speak into the microphone.
Pilot experiments revealed that these were frequently
encountered problems with nursery children performing
this experiment, and this fact contributed to the
decision to confine this experiment to older children.)

The same procedure was adopted with the Covert
group, except, of course, Ss were told to whisper the
verbal responses.   When E demonstrated what was
required prior to the first run the whisper adopted
consisted of mouthing the word, and making it just

audible.   As regards the S̲s̲, however, no distinction
was drawn in this experiment between those who whispered
in this fashion and those who whispered in a completely
inaudible fashion, perhaps even without lip movements.
In the previous experiment S̲s̲ were given a very brief
training run to check and correct method of whispering;
this was dispensed with in this experiment.   (In case
the status of these undetectable whispers should seem
suspicious, being akin to mental events in that they
are not observable, the difference between the F and the
$_cF_f$ and $_cF_s$ runs will reveal whether the whispers are
'really there' or not, by whether they have any effect,
though the problem remains that the number of such
responses cannot be checked.)

A few days after the experiment the S̲s̲ were given a
modified form of the Peabody Test (see Appendix I).

Scoring

With the Covert group, scoring simply consisted in
reading off the number of motor responses from the
counter.   With the Overt group scores were read off the
two traces on the recording paper coming from the
oscillograph.   The trace from each motor response was
always clear and unambiguous.   This was not always the
case for the verbal response where there was occasionally
the problem of detecting a signal from the background
noise.   Where the trace was obscure the same criterion
was adopted as in Exp. 2.

Results

First of all the motor scores of the Overt group will be analysed, and then the motor scores of the Covert group. Thirdly, these two groups will be compared and contrasted and, fourthly, the verbal responses of the Overt group will be examined.

In all cases, except one, the male and female Ss will be analysed together as there is no significant difference between their scores.

N.B. A purely verbal analysis of the results will be given at the beginning of the discussion section. All the symbols used below are defined on page 114 and in Fig. 25, where the information is presented in graph form.

(1) Overt Group

(i) Comparison of $_oF_f$ and $_oF_s$.

$_oF_f$ is not significantly greater than $_oF_s$ at the .05 level on a one-tailed test (T = 116.5, N = 23, on a Wilcoxon Test, where N is the number of pairs of scores whose difference is non-zero. This gives z = -.65, p < .26).

(ii) Comparison of $_oF_f$ and F.

F is greater than $_oF_f$ for every S.

(iii) Comparison of $_oF_s$ and F.

F is greater than $_oF_s$ for every S.

(iv) Comparison of $_oS_f$ and $_oS_s$.

$_oS_f$ is not significantly greater than $_oS_s$ at the

.05 level on a one-tailed test (T = 96.5, N = 22, z = -.96, p $<$ .17).

(v) Comparison of $_oS_f$ and S.

$_oS_f$ is not significantly greater than S at the .05 level on a one-tailed test (T = 90.5, N = 21, z = .85, p $<$ .20).

(vi) Comparison of $_oS_s$ and S.

S is not significantly greater than $_oS_s$ at the .5 level on a one-tailed test (T = 73.5, N = 21, z = -1.44, p $<$ .07).

(vii) Comparison of $(_oF_f - _oS_s)$ and $(_oF_s - _oS_f)$.

$(_oF_f - _oS_s)$ is not significantly greater than $(_oF_s - _oS_f)$ at the .05 level on a one-tailed test (T = 91, N = 23, z = -1.4, p $<$ .08).

(viii) Comparison of (F - S) and $(_oF_f - _oS_s)$ and $(_oF_s - _oS_f)$.

(F - S) can be compared to the maximum of the other two scores in a matched pairs test. It is found that (F - S) is significantly greater than the maximum of these two conditions at the .01 level on a two-tailed test (T = 6.5, N = 24).

(ix) Comparison of fast and slow responses within the non-verbal, command and countermand conditions.

In each case a significant discrimination was maintained.

(a) Non-verbal: F is greater than S for every S.

(b) Command: $_oF_f$ is significantly greater than $_oS_s$ at the .005 level on a one-tailed test (T = 9.5, N = 24).

(c) Countermand: $_oF_s$ is significantly greater than $_oS_f$ at the .005 level on a one-tailed test (T = 48.5, N = 24).

Fig. 25 shows the mean values, for the 24 $\underline{Ss}$ in the Overt condition, of the scores analysed above.

(2) Covert Group

(i) Comparison of $_cF_f$ and $_cF_s$.

$_cF_f$ is significantly greater than $_cF_s$ at the .025 level on a one-tailed test (T = 65, N = 22).

(ii) Comparison of $_cF_s$ and F.

F is greater than $_cF_f$ for every $\underline{S}$ but one, where F = $_cF_f$.

(iii) Comparison of $_cF_s$ and F.

F is greater than $_cF_s$ for every $\underline{S}$.

(iv) Comparison of $_cS_f$ and $_cS_s$.

(a) $_cS_f$ is not significantly greater than $_cS_s$ at the .05 level on a one-tailed test (T = 81, N = 21, z = -1.2, p < .12).

(b) If, however, only the female $\underline{Ss}$ are considered, then $_cS_f$ is significantly greater than $_cS_s$ at the .01 level on a one-tailed test (T = 5, N = 10).

(v) Comparison of $_cS_f$ and S.

$_cS_f$ is not significantly greater than S at the .05 level on a one-tailed test (T = 124, N = 22, z = -.12, p < .45).

(vi) Comparison of $_cS_s$ and S.

S is not significantly greater than $_cS_s$ at the .05

level on a one-tailed test ($T = 56$, $N = 19$, $z = -1.57$, $p < .06$).

(vii) Comparison of ($_cF_f - {_cS_s}$) and ($_cF_s - {_cS_f}$).

($_cF_f - {_cS_s}$) is significantly greater than ($_cF_s - {_cS_f}$), at the .01 level on a one-tailed test ($T = 61.5$, $N = 24$).

(viii) Comparison of ($F - S$) and ($_cF_f - {_cS_s}$) and ($_cF_s - {_cS_f}$).

As with the Overt group, ($F - S$) can be compared with the maximum of the command and countermand differences.   It is found that ($F - S$) is significantly greater than the maximum of either of these two at the .01 level on a two-tailed test ($T = 1.5$, $N = 23$).

(ix) Comparison of fast and slow responses within the non-verbal, command and countermand conditions.

In each case a significant discrimination was always maintained.

(a) Non-verbal: F is greater than S for every $\underline{S}$.

(b) Command: $_cF_f$ is greater than $_cS_s$ for every $\underline{S}$.

(c) Countermand: $_cF_s$ is greater than $_cS_f$ for every $\underline{S}$ except two. $_cF_s$ is significantly greater than $_cS_f$ at the .005 level on a one-tailed test ($T = 1$, $N = 23$).

Fig. 25 shows the mean values, for the 24 $\underline{Ss}$ in the Covert condition, of the scores analysed above.

(3) Comparison of Overt and Covert Groups

(i) Comparison of $(_c F_f - _c F_s)$ and $(_o F_f - _o F_s)$.

$(_c F_f - _c F_s)$ is not significantly greater than $(_o F_f - _o F_s)$ at the .05 level on a one-tailed test. On a Mann-Whitney test z = .29, p < .39.

(ii) Comparison of $(_c S_f - _c S_s)$ and $(_o S_f - _o S_s)$.

$(_c S_f - _c S_s)$ is not significantly greater than $(_o S_f - _o S_s)$ at the .05 level on a one-tailed test, z = .19, p < .42.

(iii) Comparison of $(_c F_f - _c S_s)$ and $(_o F_f - _o S_s)$.

$(_c F_f - _c S_s)$ is significantly greater than $(_o F_f - _o S_s)$ at the .01 level on a one-tailed test, z = 2.48, p < .007.

(iv) Comparison of $(_c F_s - _c S_f)$ and $(_o F_s - _o S_f)$.

$(_c F_s - _c S_f)$ is not significantly greater than $(_o F_s - _o S_f)$ at the .05 level on a one-tailed test, z = 1.5, p < .07.

(v) Comparison of $(F - _o F_f)$ and $(F - _c F_f)$.

$(F - _o F_f)$ is significantly greater than $(F - _c F_f)$ at the .01 level on a one-tailed test, z = 2.44, p < .007.

(vi) Comparison of $(F - _o F_s)$ and $(F - _c F_s)$.

$(F - _o F_s)$ is not significantly greater than $(F - _c F_s)$ at the .05 level on a one-tailed test, z = 1.58, p < .06.
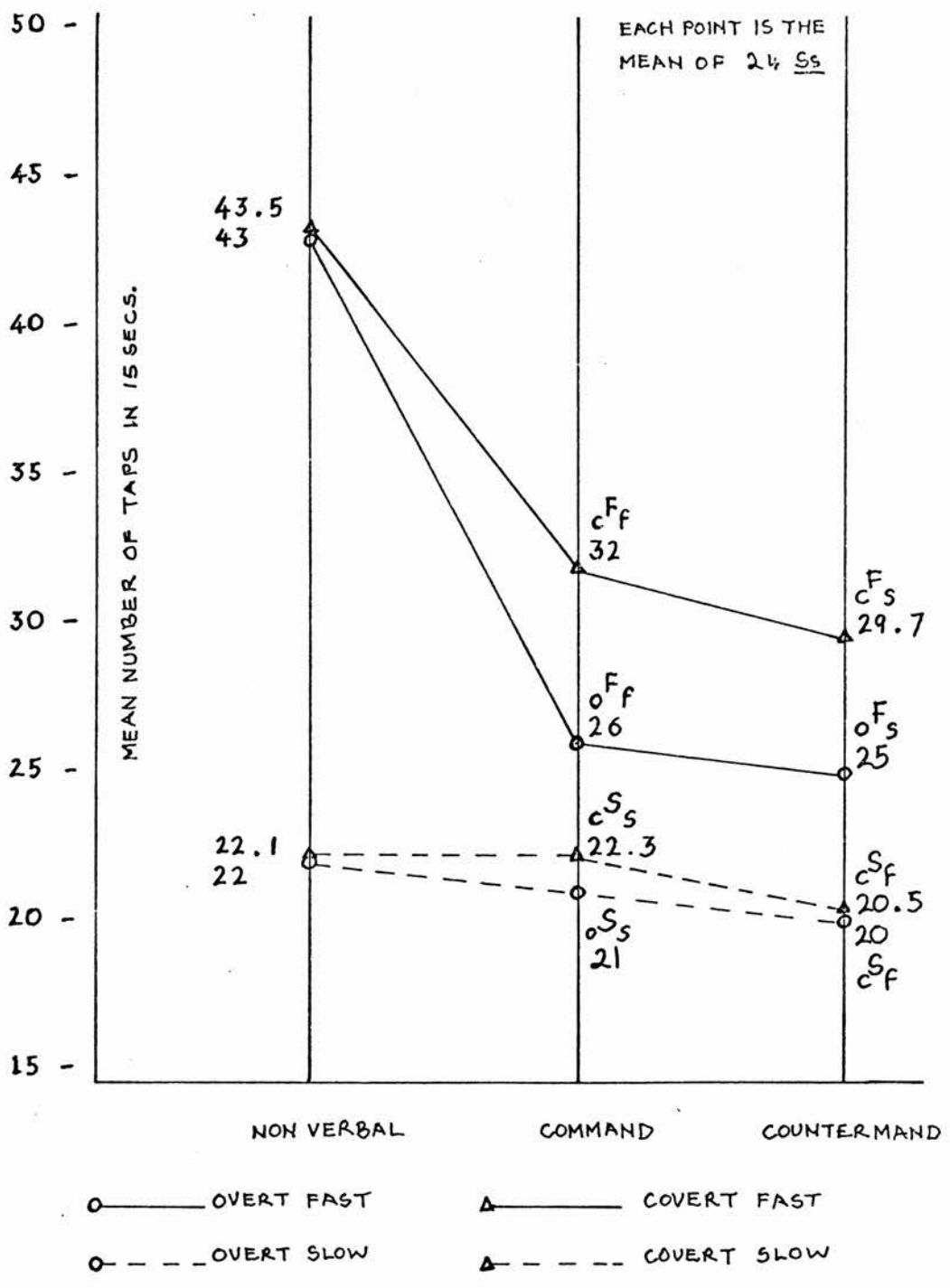
MEAN SCORES ON THE MOTOR TASKS OF EXPERIMENT 4

FIG. 25

(4) Examination of the Number of Verbal Responses

This only applies to the Overt response group.
The tests are to see if there are any correlations
between the numbers of verbal and motor responses in the
various conditions.   In one case, which will be
important later on, the comparison will be between the
number of verbal responses made in two conditions.

(i) Number of verbal and motor responses in the F_f
condition.

Calculating Spearman's Rank Correlation Coefficient
gives $r_s = .28$.   This is not significant at the .1
level on a two-tailed test.

(ii) Number of verbal and motor responses in the F_s
condition.

$r_s = .59$, which is significant at the .02 level on
a two-tailed test.

(iii) Number of verbal and motor responses in the S_f
condition.

$r_s = -.48$, which is significant at the .1 level on
a two-tailed test, but not at the .05 level.

(iv) Number of verbal and motor responses in the S_s
condition.

$r_s = -.33$, which is not significant at the .1 level
on a two-tailed test.

(v) Comparison of number of verbal responses in $_oF_f$
and $_oF_s$ conditions.

There is no significant difference at the .05 level
on a two-tailed test between these conditions ($U = 275$,
$z = -.25$, $p < .8$).

Discussion

First, the large quantity of data analysed above
will be simplified by sifting out some empirical
regularities.   The results, as they apply to the Overt
and Covert groups separately, can be summed up in three
generalisations per group.

Overt Group

(1)   Ss can maintain a discrimination between fast and
      slow responses regardless of whether they are
      overtly telling themselves what to do or the
      opposite of what they are to do.   In the non-
      verbal condition, however, this discrimination is
      better, i.e. F - S is larger, than in either the
      command or countermand conditions, which do not
      differ significantly.

(2)   If Ss overtly tell themselves what to do, this does
      not significantly affect performance compared with
      telling themselves the opposite of what they are to
      do.   That is, saying 'fast' does not make Ss tap
      faster than saying 'slow', and this regardless of
      whether the task is rapid or slow tapping.

(3)   The outstanding fact, though, is that saying either
      'fast' or 'slow' slows down the task of rapid
      tapping very significantly.   It does not, however,
      affect the task of slow tapping.

The corresponding three generalisations for the
Covert group are, in a number of respects, very
different.

Covert Group

(1) Ss can maintain a discrimination between fast and
slow responses regardless of whether they are
covertly telling themselves what to do or the
opposite of what they are to do.   In the non-
verbal condition this discrimination is at its
greatest, and significantly greater than in the
command condition.   This, in turn, is signifi-
cantly larger than in the countermand condition.

(2) Covertly saying 'fast' is associated with faster
tapping than when Ss are covertly saying 'slow'.
This applies to the task of rapid tapping, and
also, in the case of the group of female Ss, for
slow tapping.

(3) Again, covertly saying either 'fast' or 'slow'
significantly slows down the rate of rapid
tapping.   Slow tapping is not affected.

The relationship between the Overt and the Covert
groups can be summed up in two generalisations.

Overt and Covert Groups Compared

(1) In the Covert case discrimination between fast and
slow responses, when Ss are telling themselves what
to do (command condition), is significantly greater
than this discrimination in the Overt case for the
command condition.   This discrimination is not
significantly different as between Overt and
Covert Ss in the countermand condition.

(2) The difference between the rate of non-verbal fast
      tapping and the rate accompanied by the word 'fast'
      (command condition) is considerably greater for
      the Overt case than for the Covert case.   There
      is no corresponding difference in the countermand
      case.

The only generalisation that seems possible about
the relationship between the number of Overt verbal
responses and the number of taps made is that there is
no strong correlations between these numbers.   There
are significant correlations when the verbal response
does not correspond to the motor task, i.e. in the
countermand conditions, but not in the command conditions.

These empirical generalisations are stated in
theoretically neutral terms, so that no contentious
theory is presupposed in their formulation.   The
methodological importance of this approach has already
been brought out.

Now that the results have been formulated as a
number of empirical generalisations their bearing on the
hypotheses behind the experiment will be stated
explicitly.   Finally the theoretical significance of
the results will be explored.

Hypothesis (1): This hypothesis concerns the basic
claim that motor responses will be influenced in the
direction of the self-generated verbal instructions.
In the non-verbal condition this hypothesis is clearly

false.   The non-verbal condition does not produce a
score which is mid-way between the command and counter-
mand conditions.   In this respect Exp. 4 strongly bears
out Exp. 3.   But putting aside the non-verbal condition,
which clearly does not fit in with the simple regulatory
hypothesis, what about the relations between the command
and countermand conditions?   The hypothesis is true for
the Covert group in the fast tapping task and applies
also to the distinction between fast and slow tapping.
Thus it is true that,

$$_cF_f > {_cF_s} \quad \text{and} \quad (_cF_f - {_cS_s}) > (_cF_s - {_cS_f})$$

but all other parts of the hypothesis are false.

Hypothesis (2):   This hypothesis claims greater
regulatory control for covert than overt verbal
responses.   Only one part of this hypothesis is
correct;   that is,

$$(_cF_f - {_cS_s}) > (_oF_f - {_oS_s})$$

Hypothesis (3):   This concerns the relative decline in
the rate of rapid tapping when accompanied by overt and
covert responses.   Only one part of it - but an
important part - is supported by the experiment;   that is,

$$(F - {_oF_f}) > (F - {_cF_f})$$

The picture that emerges is a complex but
interesting one.   It seems that the experimental
results do provide some support for the Meichenbaum and
Goodman and Luria picture, and for what might be called

the 'load hypothesis', which denies a regulatory function for language.

The load hypothesis sees the verbal system as merely competing for capacity with the motor system and accounts for Meichenbaum and Goodman's results by postulating a greater loading associated with overt than covert responses at the age considered. The lapse from the non-verbal rate of rapid tapping to verbally accompanied rapid tapping is a rough but plausible index of the loading of the verbal responses. <u>Given this, then Exp. 4 establishes that overt utterance of the word 'fast', along with fast tapping, imposes a greater load than covert utterance of the same word.</u>[*] Reinforcing this fact there is also considerable evidence to support the claim that overt utterances have no regulatory function at all in the conditions investigated.

All of this fits in well with the load hypothesis. However, there is also some evidence which does not fit in neatly with this view. For example, there appear to be aspects of the covert responses which influence the motor performance and which are not explicable by simple considerations of capacity. On the view that capacity alone was relevant it would be expected that

$$c^F f = c^F s$$

when in fact it has been established that

$$c^F f > c^F s$$

So it appears that the covert verbal production of the words 'slow' and 'fast' in fact make a difference to the

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[*] There might, of course, simply be fewer covert responses.

rate of fast tapping. These results represent the
first really plausible example of the regulatory
function of language found in this study, though an alter-
native explanation still presents itself. This is that
there happened to be a greater number of covert verbal
responses of the word 'slow' than of the word 'fast',
thus explaining in capacity terms how the word appears
to regulate the motor responses. But the analysis of
the <u>overt</u> verbal responses showed that there was no
significant difference between the number of utterances
of the words 'fast' and 'slow' and it is plausible to
assume the same for the covert responses. Experimental
support for this assumption is provided by Landauer
(1962). These features of the results, then, indicate
a regulatory function for language.

There is a further line of development of the
capacity explanation of the results still to be explored.
The experimental data may perhaps be explained if the
notion of the capacity of a verbal response is refined
by introducing the idea of the 'compatibility' of two
responses. If two responses are incompatible they will
be difficult to perform together, and hence require more
channel capacity. (This idea of compatibility is akin
to that developed by Fitts and Seeger (1953) to describe
S-R relationships. Perhaps uttering the word 'slow',
given the set to tap rapidly, is a demand to perform
incompatible responses. The result that $_cP_f > _cP_s$
would then be explained. But then this theory would

have to explain why it was <u>not</u> the case that $_oP_f \rangle \, _oP_s$.
A further refinement would be required to the effect
that the different loadings due to incompatibility only
become apparent when not masked by the loadings
associated with the mode of delivery of the responses,
viz. overt or covert.   Since the overt responses have
greater loading than covert responses then the
differences between the command and countermand cases
will show up less.   This theoretical position could
also be supported by the belief that the loadings of
verbal responses, whatever their source, can only impose
up to a certain limit on the motor system, thus
indicating some built-in distribution of capacity to
different response modalities.

The load hypothesis can maintain itself, then,
given the two subsidiary hypotheses of (a) incompatibi-
lity, and (b) the complementary nature of the loadings
from incompatibility and loudness of verbal response.
But apart from the manifestly <u>ad hoc</u> character of (b)
criticisms can be levelled against (a).   For example,
the origin of the postulated incompatibility must be
explained.   To assert that saying 'slow' is incompatible
with rapid tapping is, perhaps, to accept tacitly that
the <u>meaning</u> of a verbal response is crucial when
considering how it impinges on a motor task.   But
surely the relevance of the meaning of the verbal
responses indicates that the very organisation of the
motor acts must involve a verbal element.   If this were

not the case it is difficult to see how meanings would be a factor in determining how much the verbal responses would interfere. (This is another form of the plausible metaphysical principle that likes can only interact with likes, hence meanings can only interfere with meanings.) This line of criticism certainly seems cogent, at least in as far as the notion of incompatibility in this case obviously opens the door to an explanation in terms of the very regulatory thesis that it was designed to exclude.

In summary, then, the outcome of Exps. 3 and 4 is this:

(1) Meichenbaum and Goodman seem to be justified in asserting that language does show a regulatory function in the sort of tasks investigated. Although their experiments are capable of explanation without appeal to regulatory hypotheses this does not seem to apply to the further data gathered above.

(2) The examples of language exerting a regulatory influence that have been found occur for covert but not for overt responses. This too bears out Meichenbaum and Goodman's claim. (Unfortunately because the area of conflict of the regulatory and capacity theories is in the realm of covert responses the rival claims regarding the number of such responses is not in practice decidable in the context of Exp. 4.)

(3) Although the claim that language has a regulatory function is very plausible, it seems to be what may be

called a 'second order effect'. The most significant
result of introducing language is to interfere with the
performance of motor tasks if these in any way tax the
capacity of the Ss. The interference, however, in some
circumstances varies in a way which seems to depend on
the meanings of the words used in the verbal responses.

This conclusion, that the regulatory function of
language is a second order effect, is of both practical
and theoretical significance. It indicates that in the
sort of situation investigated, the benefits of using
language to regulate behaviour are outweighed by the
disadvantages of its interfering influence. Theoreti-
cally this indicates that the experimental situations
just investigated may not be revealing the primary and
most important modes of interaction between speech and
action. The two systems obviously do have significant
interconnections, but these do not seem to have been
tapped by the above experimental approach. The only
really strong forms of regulation that come out in these
experiments are concerned with providing the initial
motor set. There do not seem to be important verbal
elements within the organisation of the ongoing motor
acts in the cases considered. In retrospect this is
perhaps not too surprising. The motor tasks involved
are repetitive and 'ballistic' in nature. They lack
the internal structuring which could indicate the
existence of verbal elements in the organisation of a
motor act. Indeed this line of thought could provide a

clue to understanding why the observed degree of
linguistic regulation was there at all, but yet so very
small and residual.   It could be hypothesised that in
the cases investigated in the last two experiments the
verbal system could gain no real purchase on the
internal organisation of the motor acts but was having
a residual effect on such factors as motivation and
attention to the goal of the activity.   To maintain a
fast tapping rate for 15 secs. requires considerable
effort and is the sort of task where encouragement would
seem to pay dividends.   Repeating the words 'fast' or
'slow' to oneself could act as a form of encouragement
(for fast or slow tapping respectively).   It might be
expected to have a slight regulatory influence by
influencing the set of the $\underline{S}$ even if it did not impinge
on the actual organisation of the responses.   To adopt
terms like 'encouragement' in an explanation is not
wholly satisfactory; but it does at least indicate
that the point of action of the observed regulatory
influence may be found in factors external to the actual
organisation of the motor acts, that is, in the factors
which determine the manner of execution of the acts.

In the light of these theoretical discussions the
next experiment will be concerned with an experimental
situation in which the motor tasks involve a considerable
element of what has been termed 'structuring'.   That is:
the tasks will require a motor response which involves
the discrimination of stimuli, their categorisation,

and then decision processes for the selection of the
appropriate response.   These decisions will require
the application of simple rules which link the stimulus
and response.

CHAPTER III

AN EXPERIMENTAL TEST OF A.R. LURIA'S THEORY
OF VERBAL SELF-REGULATION

The discussion of the two previous experiments suggested
that the sort of task in which the regulatory function
of language might reveal itself was one which involved
(a) the discrimination and categorisation of stimuli,
and (b) decision processes in which the response is
selected from some relevant ensemble. There is a sense
in which all behaviour may be said to involve these
features, but it is also clearly possible to devise
situations in which categorisation and decision
processes play a more prominent role than in the simple
tapping tasks of the last two experiments. Two experi-
ments of the required sort will now be introduced via a
brief reconsideration of the first principles of Luria's
theory as it was formulated at the end of Chap. I.

Introduction to Experiments 5 and 6

For Luria the verbal system is involved in the
organisation of motor acts because it provides a source
of overt or covert verbal self-instructions. Roughly
a child does something by first saying something.
Suppose that a $\underline{S}$ is presented with a sequence of red
and blue light signals and told to press a blue button
when a red light comes on and vice versa. The subse-
quent behaviour has for Luria the following structure:

First there will be a verbal analysis of the stimulus, is it red or blue? A covert process of labelling will take place. Then will come the verbal organisation of the motor act, having the form of a self-instruction, perhaps, 'if see red press blue', or 'red so blue'. (Compression and simplification would be expected from Vygotsky's work on inner speech.)

On the basis of this account the following predictions can be made. Suppose that a $\underline{S}$ is given a task which involves both motor responses and overt verbal responses. Suppose further that an overt verbal output is demanded which is directly counter to the postulated self-instructions, then, at the very least, an attenuation of the self-instructions might be expected. Under these circumstances the control of the motor responses should decline with the intrusion of responses evoked by the overt counter instructions. Thus, the following hypotheses can be stated:

Hypotheses

(1) Motor responses conjoined with <u>compatible</u> overt self-instructions should be performed more accurately than motor responses conjoined with <u>incompatible</u> overt self-instructions.

Adding to this the Luria thesis that, except in very young children, the verbal system is more developed and flexible than the motor system, then there should be a greater tendency for the motor system to accommodate

itself to the verbal system than _vice versa_, thus:

(2) Where the verbal system and the motor system are in
competition then the verbal system will predominate
over the motor system. Ss will tend to do what
they say rather than say what they do.

The above argument leading to these hypothesis is in
fact only a sketch: the full deduction is given in
Appendix II. The hypotheses also need stating more
precisely; this will be done after describing an
experimental situation in which they can be tested.
The basic experimental procedure is common to Exps. 5
and 6 which differ mainly in the load imposed on Ss as
measured by speed of presentation of stimuli. For this
reason the results of both experiments will be discussed
together after Exp. 6.

EXPERIMENT 5.   COMPATIBLE AND INCOMPATIBLE SELF-
INSTRUCTIONS IN A SENSORY-MOTOR TASK

Design

Ss were presented with a predetermined sequence of
light signals, some red, some blue. They were asked to
press one of two coloured buttons, one red, one blue, in
response to each signal. At the same time as pressing
the button the Ss had to make an overt verbal response,
uttering the word 'red' or 'blue', depending on the
colour of the light and the experimental condition.
There were four experimental conditions, which are
indicated below in Table 7.

TABLE 7

Experimental Conditions for Experiment 5

Condition	1		2		3		4	
Colour of Stimulus Light	Red	Blue	Red	Blue	Red	Blue	Red	Blue
Required Button Press	Red	Blue	Red	Blue	Blue	Red	Blue	Red
Required Verbal Response	Red	Blue	Blue	Red	Red	Blue	Blue	Red
Response Compatibility	Compatible		Incompatible		Incompatible		Compatible	

Note on Terminology

For the sake of brevity these experimental conditions will, from now on, simply be referred to by their number, viz. condition 2, and no further description of them will usually be given other than the occasional reminder of whether they are compatible or incompatible conditions. Reference back to the above table may be useful in following the argument. When a condition is referred to simply as 'compatible' or 'incompatible' this will refer to the relationship between the motor and verbal responses. In the discussion section a further notion of compatibility will emerge in which it refers to S-R relationships. Except when the context makes the meaning quite clear it will always be made explicit if

this second sense is intended.

Each S was given all four experimental conditions
after reaching criterion in a trial run for that
condition.   Condition 1 was always given first, after
which came conditions 2, 3 and 4, whose order was
randomised across Ss.   Finally condition 1 was re-run.
Four Ss, 2 male and 2 female, were given each of the 6
possible orders in which the experimental conditions
could be arranged on the above design.

Subjects

The 24 Ss were drawn from the Sciennes School,
Edinburgh.   The Ss were the final 24 pupils on the
register list of one of the classes.   The first half-
dozen pupils on the register had taken part in the pilot
experiments.   No S was reported by their teacher as
having sensory-motor defects, and no S had to be
eliminated because of unwillingness to cooperate in the
experiment.   Table 8 gives details of the S's ages and
scores on a modified Peabody Picture Vocabulary Test.

TABLE 8

Details of the Subjects of Experiment 5

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Score*	S.D.
Male	12	85.2	2.4	61.6	8.7
Female	12	84.4	3.0	62.5	9.4

* Raw Score.   See Appendix I.

Apparatus

The general layout of the apparatus is given in
Fig. 26.   It consisted of (i) a device which could
produce a sequence of light signals which could be
repeated for each S, and (ii) a stimulus-response unit
containing the stimulus lights and the response buttons,
plus (iii) a means of recording both the stimuli and the
responses.   The exact form of the S-R unit is also
shown below.   The light signals were generated by two
tones on a magnetic tape which actuated voice keys.
The stimuli and motor responses were recorded on a pen
recorder.   The verbal responses were recorded by E.

Stimuli

The stimulus material consisted in the following
sequence of 10 blue (B) and 10 red (R) light signals.
Each light flash lasted 1.0 sec. and the interval
between successive stimuli was 2.0 secs.

              B B R R B R R B R B R R R B B B B R B R
The sequence was preceded by a marker on the magnetic
tape which was aligned with a mark on the tape recorder
and which indicated that the first light signal of the
sequence would begin in 3 secs.   The marker did not
trigger the lights but was used by E so that there was a
constant time between his switching on the apparatus and
the first stimulus.
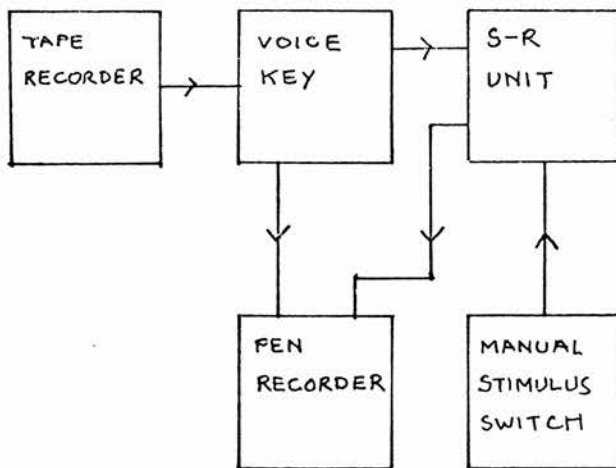
(a) GENERAL LAYOUT. THE APPARATUS FOR EXPERIMENT 5
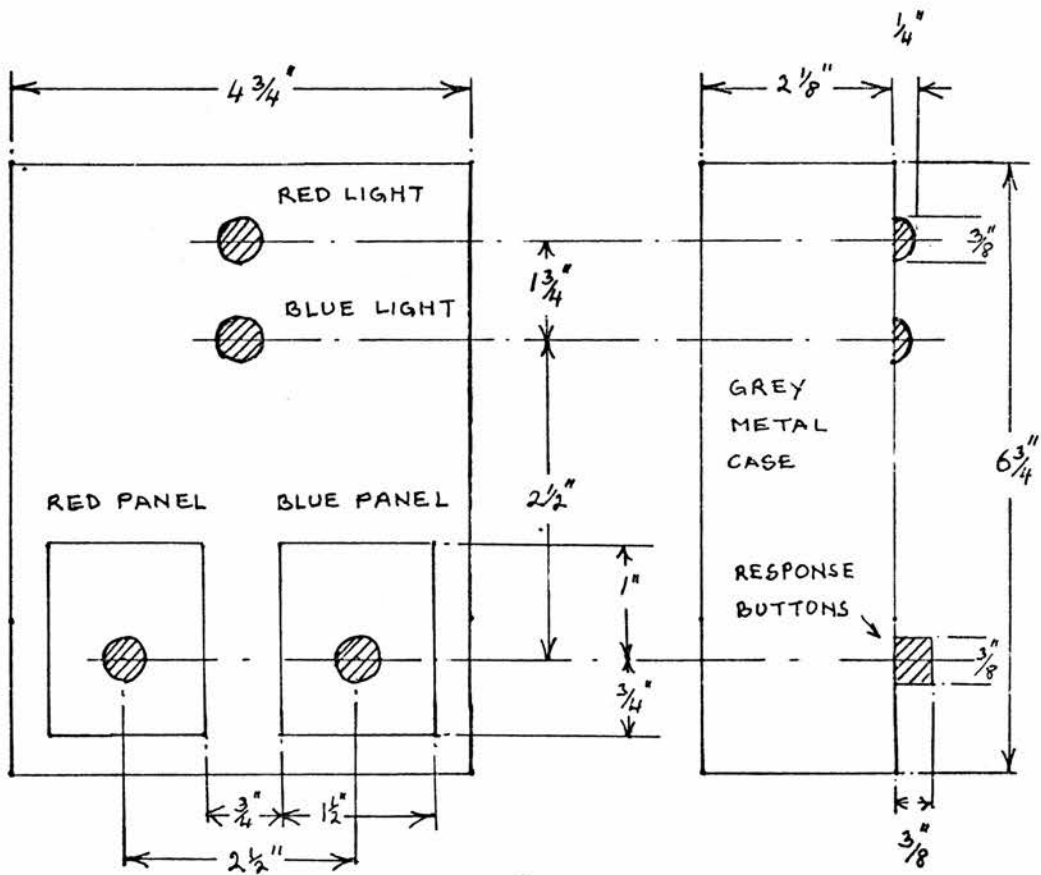
(b) DETAILS OF STIMULUS-RESPONSE UNIT (not to scale)

FIG. 26

Procedure

Ss were taken by E from their classroom to one nearby which housed the apparatus. They were then seated at a table with E next to them and shown the stimulus lights and response buttons. Whilst operating the lights manually E explained that 'every time the red light comes on (flash red light) I want you to press the red button and say "red!" in a nice loud voice...like this (E demonstrates)...and every time the blue light comes on press the blue button and say "blue!"... (E again demonstrates). S was then invited to try and E manually produced the test sequence R B R R B B. The sequence was repeated until S could produce one complete set of motor and verbal responses for the sequence. The speed of presentation of the test was approximately that used during an experimental run, the first of which was then presented.

Ss were told that the machine that they could see would switch the lights on and off to save E the trouble and they were to do just what they had been doing. E reminded S of the instructions and switched on the pen recorder and then the tape recorder to work the lights. As the tape recorder was switched on the S was told, 'get ready!' E recorded Ss' verbal responses on a checklist noting against each light signal whether the verbal response was R or B. During the experimental runs E did not look at S in order that S would not be distracted. When the sequence was complete and the

apparatus switched off the S was told that he had done well and that something different would now be tried. E then adjusted the tape recorder to ensure that the marker for the next run was in place and then demonstrated the next set of stimuli and responses. Apart from appropriate substitutions the presentation of the instructions and the test sequence was exactly the same from run to run, and the instructions were always repeated immediately before each run.

On completion of all of the experimental conditions the Ss were thanked and returned to the classroom. The total time for the experiment varied from S to S depending on the amount of practice required, but was in the region of 10 minutes. Most Ss needed only one or two test runs and none more than half a dozen.

On only 5 out of a total of 120 individual experimental runs did Ss become muddled as soon as the light sequence started, i.e. making no responses and telling E that they had forgotten the instructions. On two other runs Ss stopped responding in the middle of a sequence and announced that they had forgotten what to do. In these circumstances the sequence was immediately stopped, the Ss reassured and the training sequence and instructions for the relevant run repeated. Only one S produced more than one interruption and on both occasions it was at the beginning of a run before any responses had been made. In none of the cases was the S discarded. In view of the complexity of the experimental task it

was perhaps surprising that there were not significantly more cases like this.

One final detail of procedure concerns the use of the preferred hand for button pressing. If Ss tended to use both hands in the motor task they were asked to press with only one hand, keeping the other in their lap. If they seemed undecided as to which hand to use they were told to use the hand that they write with. In the experimental runs Ss occasionally resorted to using one hand for each button. Ss were not stopped in mid run from doing this but were gently reminded during the next test sequence to use only one hand.

Scoring Criterion

A motor response was defined as a button press sufficient to cause deflection of the pen recorder. The pen recorder was so arranged that it recorded only two signal values, on or off. A deflection in one direction indicated that the blue button had been pressed, one in the other direction that the red button had been pressed. A similar on/off arrangement applied to the recording of the red and blue lights.

Any response trace which began after the onset of a stimulus trace, and before or at the beginning of the next stimulus trace, was deemed a response to the first stimulus. The very occasional second extra responses to a stimulus was ignored.

As indicated earlier verbal responses were recorded

by E.   Here again second responses were ignored.   Thus
corrections like, 'red...no! blue', were counted as red,
though the occasional 'r...blue!' was counted as blue.
In no case was E aware that a verbal response had been
made which could not be clearly discriminated as 'red'
or 'blue'.*

Ignoring extra responses, which previous work has
shown to be both rare and unrevealing, there are three
important classes of response:

(C) correct responses, whether motor or verbal;

(I) intrusions of opposite motor or verbal responses;

(M) missing motor or verbal responses.

This classification now permits a clearer statement of
the hypotheses to be tested.

Restatement of Hypotheses

Remember that experimental conditions 1 and 4 are
such that the motor and verbal responses are compatible
with one another whereas in conditions 2 and 3 they are
incompatible.   The first hypothesis then breaks down
into three parts.

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* It is legitimate to criticise this method of recording
responses because of its lack of objectivity.
Originally the apparatus had been designed to record a
trace of the verbal response and this would have
provided at least a partial check.   It transpired,
however, that the sensitivity of the microphone could
not be adjusted to capture all the verbal responses
without recording a great deal of extraneous noise.
In pilot experiments Ss' verbal responses had also
been recorded on a tape recorder which enabled E to
check the accuracy of his own records.   Since there
was complete agreement between E's records and the
tapes this further check was also discarded, to
simplify the conduct of the experiment.

(1.1) The combined number of correct motor responses of
conditions 2 and 3 will be less than the combined
number of correct responses of conditions 1 and 4.

(1.2) The combined number of missing motor responses in
conditions 2 and 3 will be greater than the
combined number of missing motor responses in
conditions 1 and 4.

(1.3) The combined number of intrusive (opposite) motor
responses in conditions 2 and 3 will be greater
than the combined number of intrusive motor
responses in conditions 1 and 4.

The second hypothesis becomes:

(2) The combined number of intrusive (opposite) motor
responses in conditions 2 and 3 will be greater
than the combined number of intrusive verbal
responses in conditions 2 and 3.

The results of Exp. 5 will now be analysed.   The
analysis will be taken further than is required for
merely judging the above hypotheses.   This is to
provide extra material that will be used in the
discussion section that will follow the account of
Exp. 6.

Results

The graphs below give the mean motor and verbal
scores for the various experimental conditions.

MEAN NUMBER OF CORRECT MOTOR RESPONSES

FIG. 27

MEAN NUMBER OF MISSING MOTOR RESPONSES
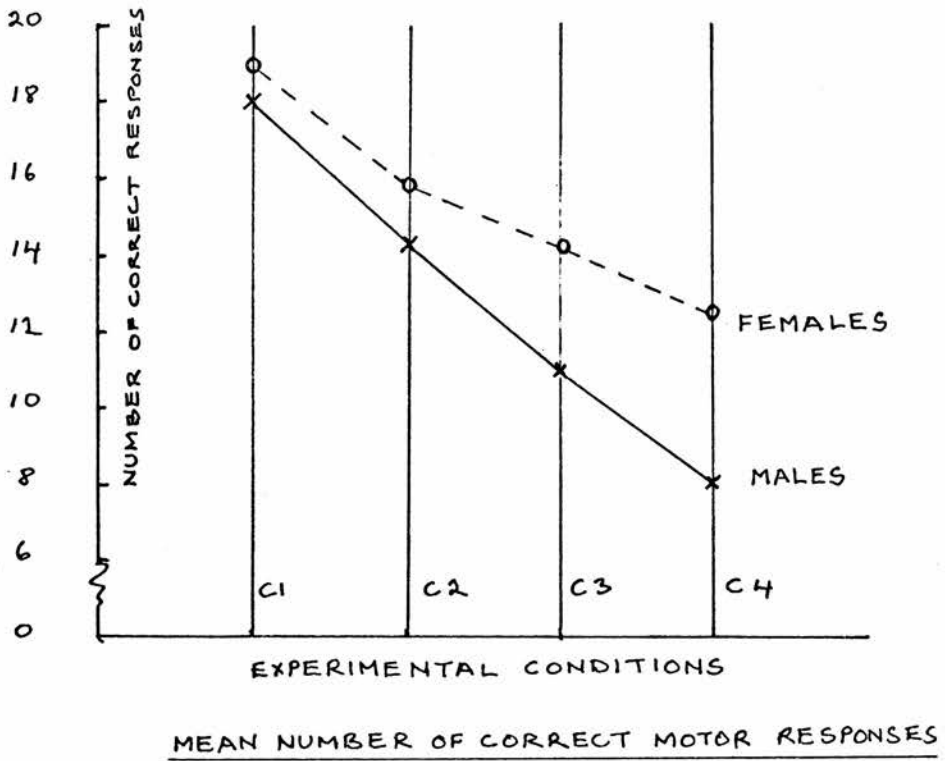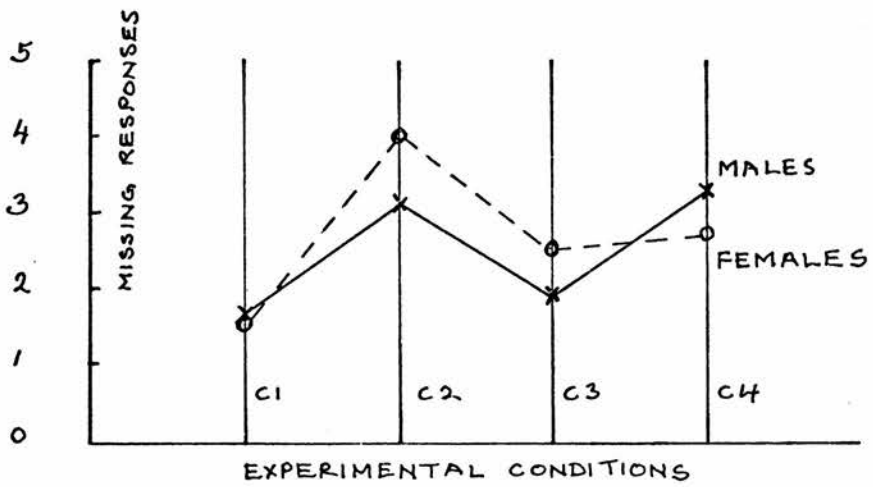
FIG. 28
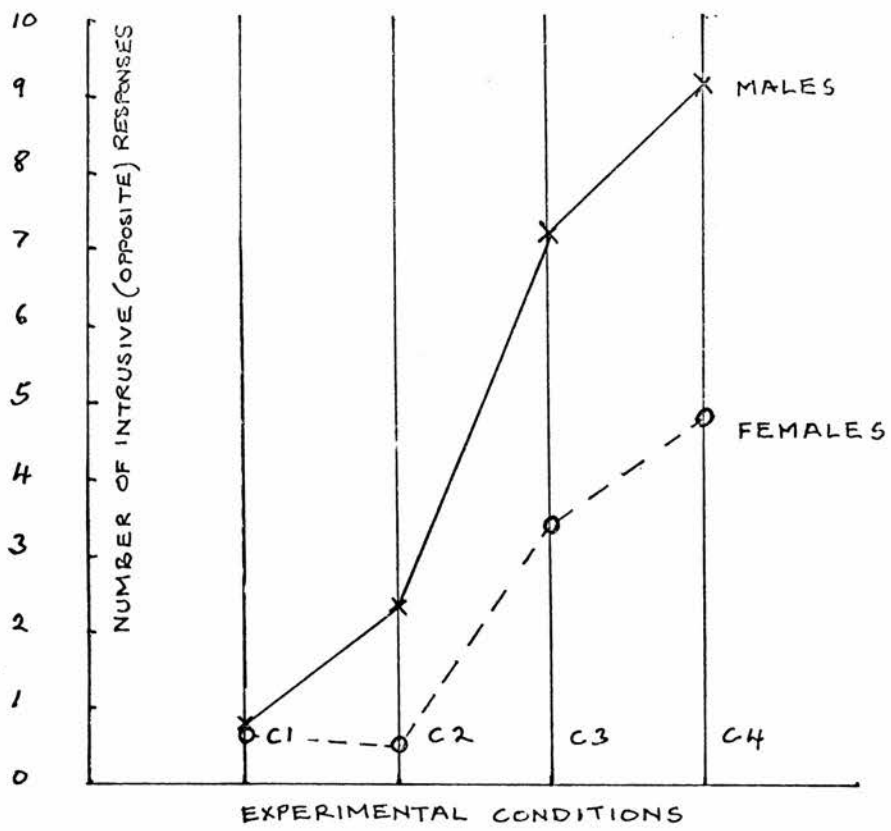
MEAN NUMBER OF INTRUSIVE (OPPOSITE) MOTOR RESPONSES

FIG. 29
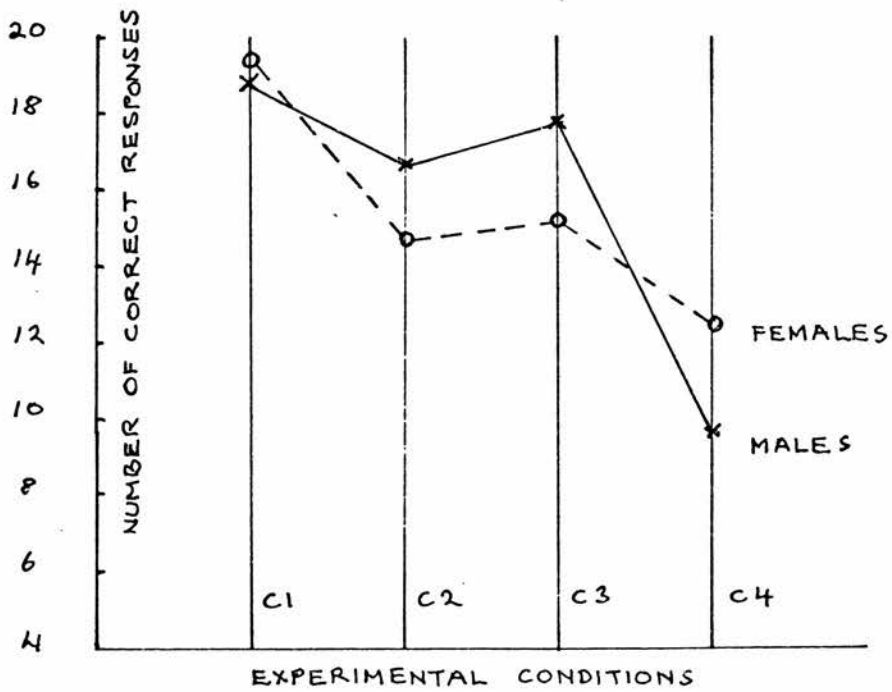
MEAN NUMBER OF CORRECT VERBAL RESPONSES

FIG. 30
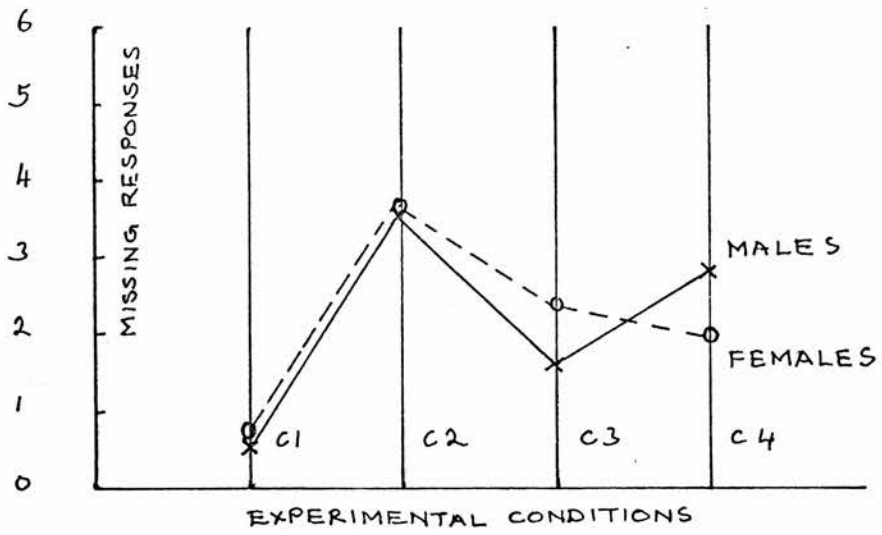
MEAN NUMBER OF MISSING VERBAL RESPONSES

FIG. 31
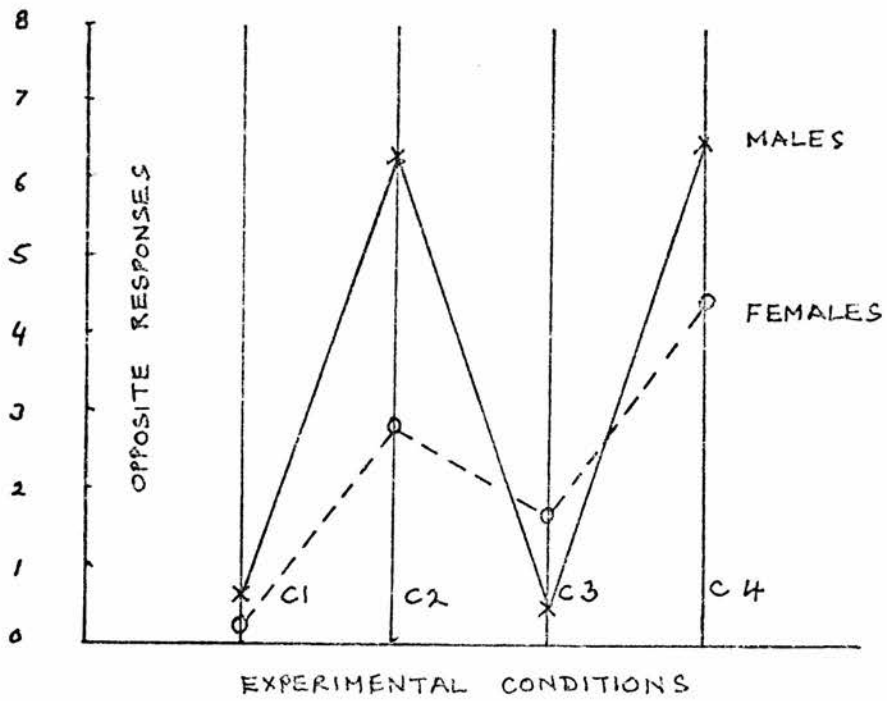
MEAN NUMBER OF INTRUSIVE (OPPOSITE) VERBAL RESPONSES

FIG 32

To test Hypothesis 1 the combined motor scores in conditions 2 and 3 are compared to the combined motor scores in conditions 1 and 4.

TABLE 9

Combined Motor Scores in Conditions 1 and 4
compared with Combined Motor Scores in
Conditions 2 and 3 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	T = 18.5 (NS)	T = 14.5 (NS)	T = 18.5 (NS)
	N = 11	N = 10	N = 10
Female	T = 19.5 (NS)	T = 5.0*	T = 21 (NS)
	N = 11	N = 11	N = 9
Combined	T = 70.5 (NS)	T = 34.5*	T = 81 (NS)
	N = 22	N = 21	N = 19

* Sig. at .005 level on a one-tailed Wilcoxon Test.

TABLE 10

Comparison of Motor Scores in
Conditions 1 and 2 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	T = 3*	T = 2*	T = 15 (NS)
	N = 12	N = 11	N = 11
Female	T = 13.5 +	T = 12 +	T = 3.5 (NS)
	N = 12	N = 12	N = 4
Combined	T = 27*	T = 25.5*	T = 30 (NS)
	N = 24	N = 23	N = 15

* Sig. at .005 level on a one-tailed Wilcoxon Test.

+ " " .025 " " " " " "

TABLE 11

Comparison of Motor Scores in
Conditions 1 and 3 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 8.5^{*}$	$T = 23$ (NS)	$T = 3.5 +$
	$N = 12$	$N = 10$	$N = 9$
Female	$T = 2.5^{**}$	$T = 4^{*}$	$T = 0^{**}$
	$N = 11$	$N = 10$	$N = 8$
Combined	$T = 17^{**}$	$T = 47.5 +$	$T = 4^{**}$
	$N = 23$	$N = 20$	$N = 17$

* Sig. at .01 level on a one-tailed Wilcoxon Test.

** " " .005 " " " " " "

\+ " " .025 " " " " " "

To test Hypothesis 2 the motor intrusions are
compared with the verbal intrusions in conditions 2 and 3.

TABLE 12

Comparison of the Motor and Verbal Scores
when Conditions 2 and 3 of Experiment 5 are Combined

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 8.5$ (NS)	$T = 18$ (NS)	$T = 0^{*}$
	$N = 10$	$N = 10$	$N = 9$
Female	$T = 25.5$ (NS)	$T = 8$ (NS)	$T = 22$ (NS)
	$N = 10$	$N = 5$	$N = 9$
Combined	$T = 73.5$ (NS)	$T = 44.5$ (NS)	$T = 44.5$ (NS)
	$N = 20$	$N = 15$	$N = 18$

* Sig. at .005 level on a one-tailed Wilcoxon Test.

Comparison of the motor scores on runs 2, 3 and 4.

TABLE 13

Comparison of Motor Scores in
Conditions 2 and 4 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	T = 15 (NS)	T = 13 (NS)	T = 12 (NS)
	N = 12	N = 7	N = 11
Female	T = 13.5 (NS)	T = 6[+]	T = 3 (NS)
	N = 10	N = 9	N = 7
Combined	T = 73 (NS)	T = 37.5 (NS)	T = 25.5[#]
	N = 22	N = 16	N = 18

[#] Sig. at .01 level on a two-tailed Wilcoxon Test.

[+] " " .05 " " " " " "

TABLE 14

Comparison of Motor Scores in
Conditions 3 and 4 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	T = 2[#]	T = 6[+]	T = 17 (NS)
	N = 11	N = 11	N = 9
Female	T = 17.5 (NS)	T = 22 (NS)	T = 19.5 (NS)
	N = 10	N = 10	N = 9
Combined	T = 50[##]	T = 80 (NS)	T = 74.5 (NS)
	N = 21	N = 21	N = 18

[#] Sig. at .01 level on a two-tailed Wilcoxon Test.

[+] " " .02 " " " " " "

[##] " " .05 " " " " " "

The motor responses in the compatible runs will now be compared to one another.

TABLE 15
Comparison of Motor Scores in
Conditions 1 and 4 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 0^{*}$	$T = 4^{+}$	$T = 0^{*}$
	$N = 12$	$N = 10$	$N = 10$
Female	$T = 1^{*}$	$T = 14.5$ (NS)	$T = 15^{**}$
	$N = 10$	$N = 8$	$N = 7$
Combined	$T = 2^{*}$	$T = 94$ (NS)	$T = 2^{*}$
	$N = 22$	$N = 18$	$N = 17$

$*$ Sig. at .01 level on a two-tailed Wilcoxon Test.
$+$ " " .02 " " " " " "
$**$ " " .05 " " " " " "

Comparison of the motor responses in the incompatible runs.

TABLE 16
Comparison of Motor Scores in
Conditions 2 and 3 of Experiment 5

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 33$ (NS)	$T = 4^{+}$	$T = 10$ (NS)
	$N = 12$	$N = 10$	$N = 9$
Female	$T = 28$ (NS)	$T = 23$ (NS)	$T = 4^{**}$
	$N = 11$	$N = 11$	$N = 9$
Combined	$T = 114$ (NS)	$T = 53.5^{**}$	$T = 29.5^{*}$
	$N = 23$	$N = 21$	$N = 18$

$*$ Sig. at .01 level on a two-tailed Wilcoxon Test.
$+$ " " .02 " " " " " "
$**$ " " .05 " " " " " "

Comparison of intrusive motor and verbal responses
within each of the incompatible conditions.

TABLE 17

Comparison of Intrusive Motor and Verbal Responses in Conditions 2 and 3 of Experiment 5

Subjects	Condition 2	Condition 3
Male	$T = 8$ (NS) $N = 8$	$T = 0$[*] $N = 7$
Female	$T = 8$ (NS) $N = 8$	$T = 7.5$ (NS) $N = 8$
Combined	$T = 29$[+] $N = 16$	$T = 9.5$[*] $N = 15$

[*] Sig. at .01 level on a two-tailed Wilcoxon Test.
[+] " " .05 " " " " " "

These results will be discussed in conjunction with
those of the next experiment.

EXPERIMENT 6. COMPATIBLE AND INCOMPATIBLE SELF-INSTRUCTIONS IN A SENSORY-MOTOR TASK: II. EFFECT OF INCREASE IN LOAD

This experiment is essentially the same as Exp. 5
except that (a) it is performed on a different and
slightly younger group of children, and (b) the
presentation of the stimuli was considerably more rapid
than in the above. Exp. 6 thus tests Luria's theory
under conditions of increased task load. Because the
hypotheses, experimental design, apparatus and procedure

were identical to Exp. 5 only those features which differed will be described below.

Subjects

The Ss were drawn from another class of the same school used in Exp. 5. As before the final 12 boys and 12 girls on the register were used, the remainder taking part in pilot experiments. Again no S had to be eliminated through sensory-motor defects or through unwillingness to cooperate. Details are given in Table 18 below.

TABLE 18

Details of the Subjects of Experiment 6

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Test Score[*]	S.D.
Male	12	80.1	2.4	68.6	10.1
Female	12	79.9	2.3	68.3	7.2

[*] Raw Score. See Appendix I.

Stimuli

Exactly the same sequence of lights were used as in Exp. 5 but the speed of the tape recorder which drove the lamps was increased. This produced a sequence of signals of 0.5 sec. duration, with an inter-stimulus interval of 1.0 sec. The duration of the preparation period between the tape recorder being switched on and the sequence beginning was 1.0 sec. The test sequence

was manually delivered at the same speed as in Exp. 5.

Scoring Methods and Criteria

These were exactly the same as in Exp. 5 except for one slightly different convention that had to be adopted because of the faster pace of the tasks. This concerned the verbal responses which were still recorded by E. Because of the high speed of responding it was found, in pilot experiments, that E could not be confident that the record of the verbal response had been entered against the right stimulus. This problem was aggravated by the fact that the greater difficulty of the task meant that some Ss were only able to produce isolated responses which were particularly difficult to locate. To solve this problem the following scoring convention was adopted for the verbal responses: verbal responses were scored so as to maximise the number of correct responses and minimise the number of intrusions. Thus in a condition requiring the response 'blue' to a red light an isolated 'blue' would be assumed to be a response to a red rather than blue light. This convention works to the Ss' favour in the C and I scores but leaves the reliability of the missing response score (M) unchanged. When necessary, account will be taken of this fact when discussing the results.

The scoring convention for the motor responses was exactly the same as in Exp. 5.

Results

These will be analysed in the same order as in Exp. 5.
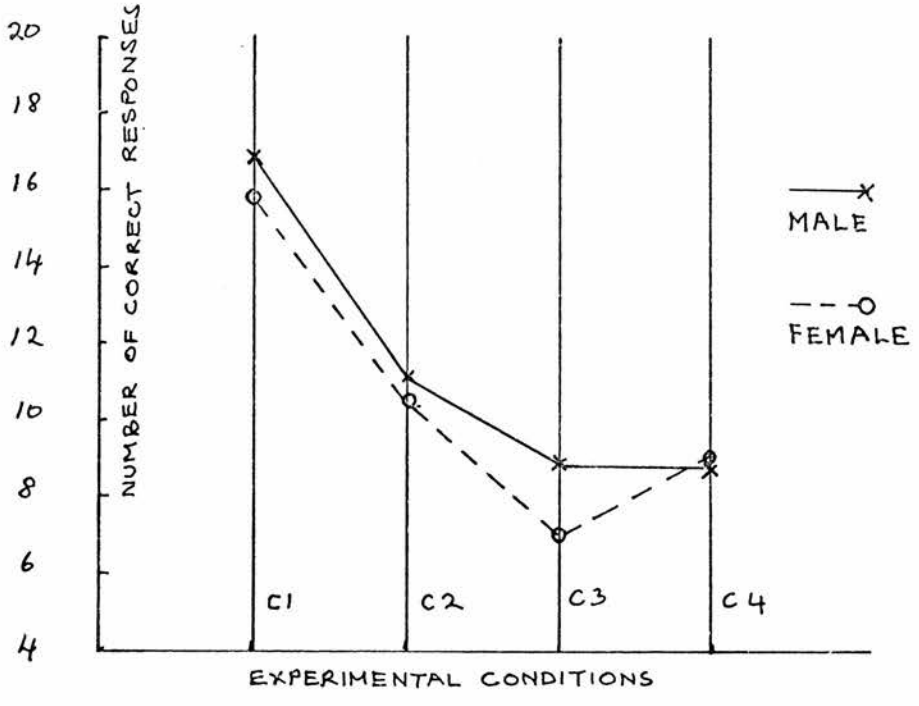
MEAN NUMBER OF CORRECT MOTOR RESPONSES

FIG 33
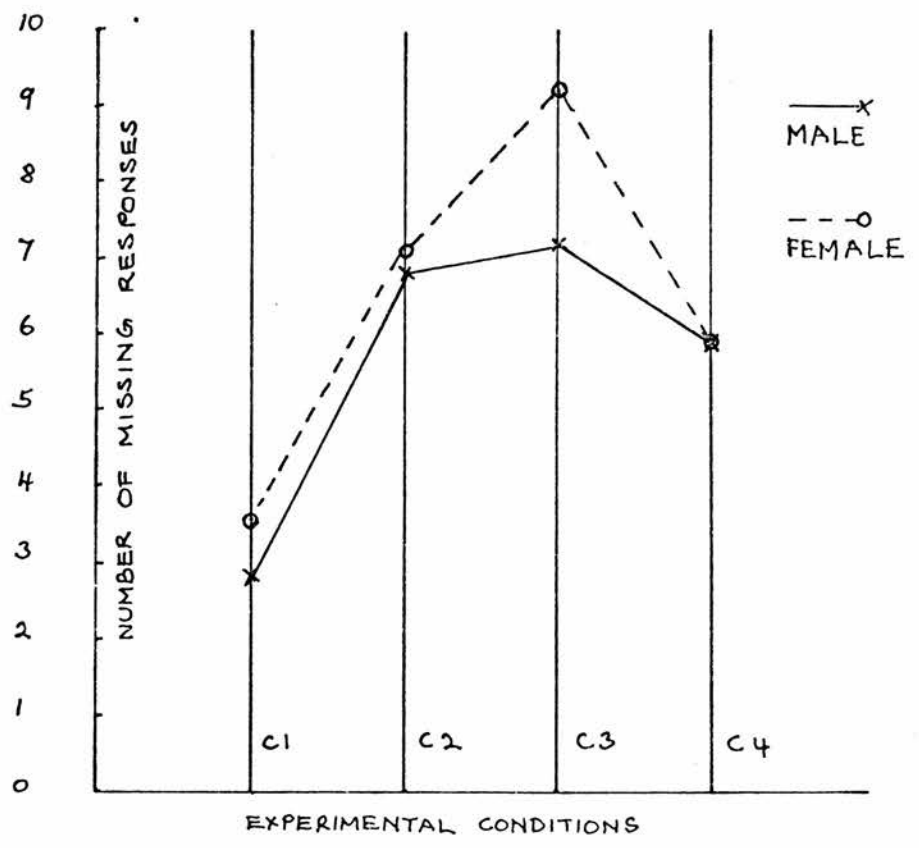
MEAN NUMBER OF MISSING MOTOR RESPONSES

FIG. 34
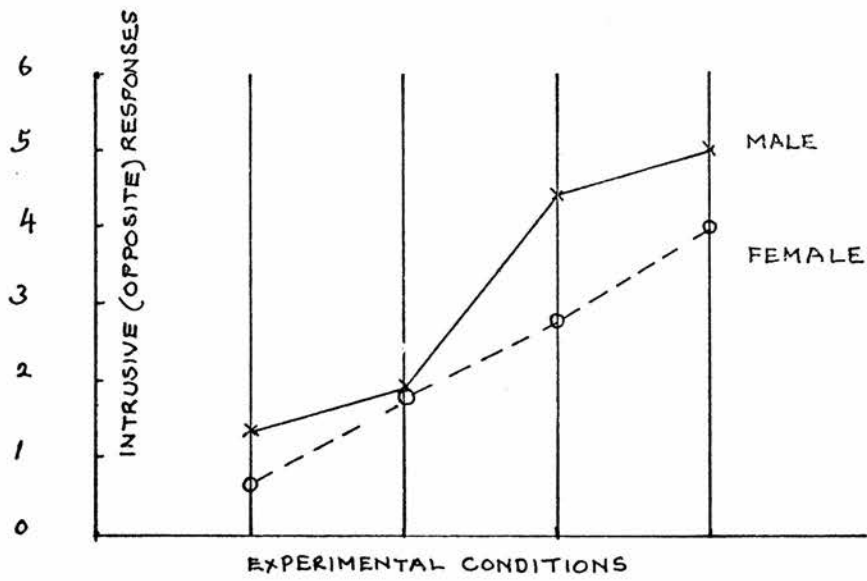
MEAN NUMBER OF INTRUSIVE (OPPOSITE) MOTOR RESPONSES

FIG. 35
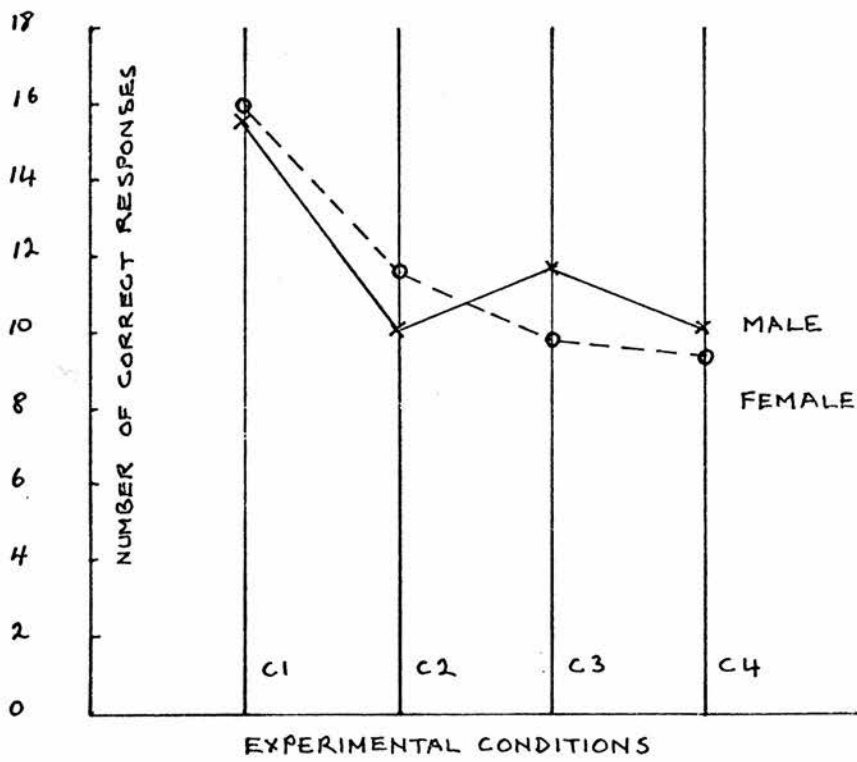
MEAN NUMBER OF CORRECT VERBAL RESPONSES

FIG. 36
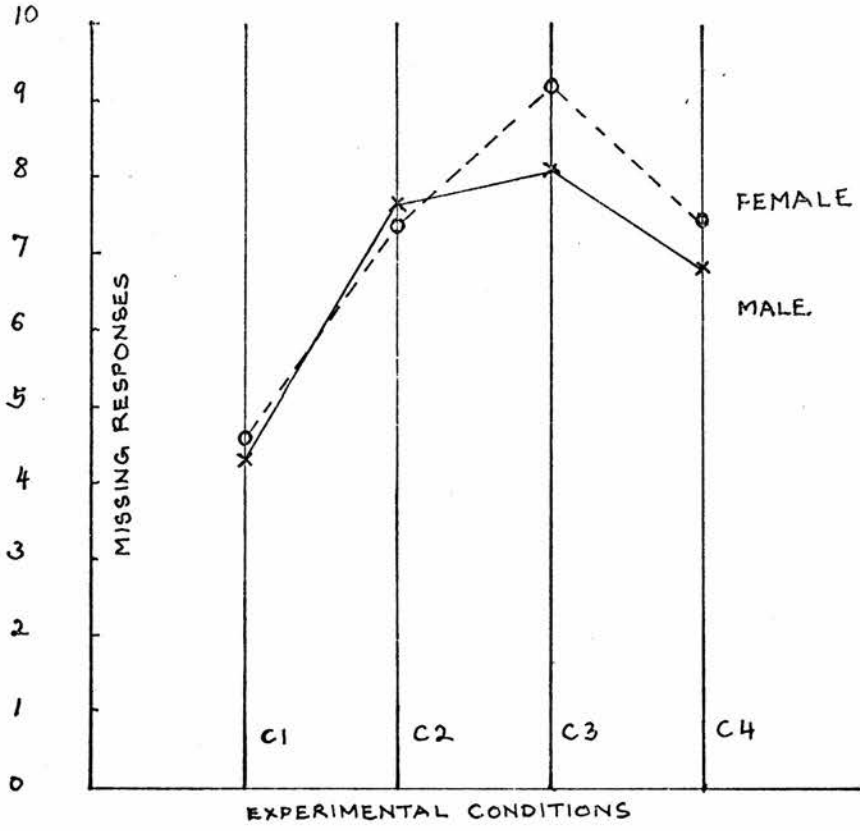
MEAN NUMBER OF MISSING VERBAL RESPONSES

FIG. 37
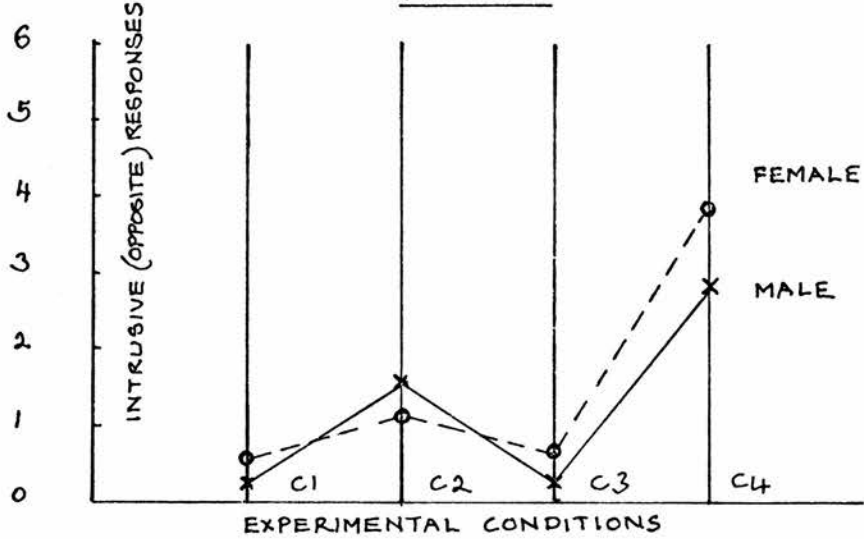
MEAN NUMBER OF INTRUSIVE (OPPOSITE) VERBAL RESPONSES

FIG 38

To test Hypothesis I the combined motor scores in conditions 1 and 4 are compared with the same score in conditions 2 and 3.

TABLE 19

Combined Motor Scores in Conditions 1 and 4 compared with Combined Motor Scores in Conditions 2 and 3 of Experiment 6

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	T = 16 (NS)	T = 5*	T = 37 (NS)
	N = 12	N = 12	N = 12
Female	T = 6*	T = 8.5+	T = 31.5 (NS)
	N = 12	N = 12	N = 12
Combined	T = 37.5*	T = 25.5*	T = 141 (NS)
	N = 24	N = 24	N = 24

* Sig. at .005 level on a one-tailed Wilcoxon Test.
+ " " .01 " " " " " "

TABLE 20

Comparison of Motor Scores in Conditions 1 and 2 of Experiment 6

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	T = 1.5*	T = 2.5*	T = 14 (NS)
	N = 11	N = 12	N = 9
Female	T = 2*	T = 10+	T = 13.5 (NS)
	N = 12	N = 12	N = 11
Combined	T = 6.5*	T = 24*	T = 43.5+
	N = 23	N = 24	N = 20

* Sig. at .005 level on a one-tailed Wilcoxon Test.
+ " " .01 " " " " " "

TABLE 21
Comparison of Motor Scores in Conditions 1 and 3
of Experiment 6

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 1^{*}$	$T = 1.5^{*}$	$T = 12^{**}$
	$N = 12$	$N = 12$	$N = 12$
Female	$T = 0^{*}$	$T = 5^{*}$	$T = 8.5^{+}$
	$N = 12$	$N = 11$	$N = 12$
Combined	$T = 1^{*}$	$T = 16.5^{*}$	$T = 38^{*}$
	$N = 24$	$N = 23$	$N = 24$

$*$ Sig. at .005 level on a one-tailed Wilcoxon Test.

$+$ " " .01 " " " " " "

$**$ " " .025 " " " " " "

Data relevant to Hypothesis 2.

TABLE 22
Comparison of Motor and Verbal Scores when
Conditions 2 and 3 of Experiment 6 are combining

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 19$ (NS)	$T = 15.5$ (NS)	$T = 12$ (NS)
	$N = 10$	$N = 9$	$N = 10$
Female	$T = 1^{*}$	$T = 21.5$ (NS)	$T = 11^{**}$
	$N = 9$	$N = 9$	$N = 11$
Combined	$T = 36.5^{*}$	$T = 72$ (NS)	$T = 44^{+}$
	$N = 19$	$N = 18$	$N = 21$

$*$ Sig. at .005 level on a one-tailed Wilcoxon Test.

$+$ " " .01 " " " " " "

$**$ " " .025 " " " " " "

Comparison of the motor scores in conditions 2, 3 and 4.

TABLE 23

Comparison of Motor Scores in Conditions 2 and 4

of Experiment 6

Subjects	Correct (C)		Missing (M)		Intrusions (I)	
Male	T = 32	(NS)	T = 13	(NS)	T = 16	(NS)
	N = 11		N = 10		N = 11	
Female	T = 32	(NS)	T = 13.5	(NS)	T = 10	(NS)
	N = 12		N = 10		N = 8	
Combined	T = 126.5	(NS)	T = 50.5*		T = 143.5	(NS)
	N = 23		N = 20		N = 19	

* Sig. at .05 level on a two-tailed Wilcoxon Test.

TABLE 24

Comparison of Motor Scores in Conditions 3 and 4

of Experiment 6

Subjects	Correct (C)		Missing (M)	Intrusions (I)	
Male	T = 33	(NS)	T = 21 (NS)	T = 30	(NS)
	N = 12		N = 11	N = 11	
Female	T = 22	(NS)	T = 8.5*	T = 27	(NS)
	N = 12		N = 11	N = 10	
Combined	T = 104	(NS)	T = 52.5+	T = 103	(NS)
	N = 24		N = 22	N = 21	

+ Sig. at .02 level on a two-tailed Wilcoxon Test.

* " " .05 " " " " " "

Motor responses in compatible conditions compared with one another.

TABLE 25
Comparison of Motor Scores in Conditions 1 and 4 of Experiment 6

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 0^*$	$T = 3^*$	$T = 2.5^*$
	$N = 11$	$N = 12$	$N = 12$
Female	$T = 1^*$	$T = 7^+$	$T = 11^+$
	$N = 11$	$N = 11$	$N = 12$
Combined	$T = 2^*$	$T = 22^*$	$T = 28.5^*$
	$N = 22$	$N = 23$	$N = 24$

* Sig. at .01 level on a two-tailed Wilcoxon Test.
+ " " .02 " " " " " "

Motor responses in incompatible conditions compared with one another.

TABLE 26
Comparison of Motor Scores in Conditions 2 and 3 of Experiment 6

Subjects	Correct (C)	Missing (M)	Intrusions (I)
Male	$T = 19$ (NS)	$T = 27$ (NS)	$T = 3.5$ (NS)
	$N = 12$	$N = 11$	$N = 7$
Female	$T = 12^+$	$T = 16$ (NS)	$T = 1.5$ (NS)
	$N = 12$	$N = 12$	$N = 6$
Combined	$T = 49^*$	$T = 78.5$ (NS)	$T = 8^*$
	$N = 24$	$N = 23$	$N = 13$

* Sig. at .01 level on a two-tailed Wilcoxon Test.
+ " " .025 " " " " " "

Comparison of the intrusive motor and verbal responses within each of the two incompatible conditions.

TABLE 27

Comparison of Intrusive Motor and Verbal Responses
in Conditions 2 and 3 of Experiment 6

Subjects	Condition 2	Condition 3
Male	T = 15 (NS)	T = 0*
	N = 8	N = 9
Female	T = 9 (NS)	T = 0*
	N = 8	N = 9
Combined	T = 44.5 (NS)	T = 0*
	N = 16	N = 18

* Sig. at .01 level on a two-tailed Wilcoxon Test.

Discussion and Further Analysis

First, the experimental data will be related to Hypotheses 1 and 2. Second, an alternative to the Luria theory will be developed and also compared with the experimental data. Especially important will be data relating to points where the predictions of the two theories diverge.

Discussion of Hypothesis 1

Hypothesis 1 states that motor performance under compatible conditions, that is, accompanied by commands, should be more efficient than under incompatible conditions, that is, accompanied by countermands.

(Let the different speeds of presentation of the stimuli
in Exps. 5 and 6 be indicated by calling the Ss of Exp. 5
the low-load group and those of Exp. 6 the high-load
group.)   For neither the high- nor the low-load group
is the hypothesis confirmed for the intrusive responses.
The hypothesis is borne out for the high-load group only
as far as correct responses are concerned, but by both
groups as regards missing responses.   So the compati-
bility of the motor and verbal tasks seems important
especially with regard to missing motor responses.
Hypothesis 1 is thus supported to some extent, though
not very strongly.

Discussion of Hypothesis 2

Hypothesis 2 states that where the verbal and motor
responses are in opposition, i.e. in incompatible
conditions, then there will be more intrusions of
opposite responses into the motor than into the verbal
outputs.   This is not borne out at all for the low-load
groups taken as a whole, though it is true for the male
Ss taken alone.   For the high-load groups on the other
hand, it is not true for the male Ss, but it is true for
the female Ss taken alone and for the male and female Ss
taken as a whole.   For the high-load group, then, Hypo-
thesis 2 is fairly strongly supported, though it is only
very weakly supported for the low-load group.   It must
also be borne in mind that the scoring convention
biases the results in favour of the hypothesis.

Overall, the two hypotheses derived from Luria's theory gain a certain amount of support from the experimental results, but neither hypothesis is very strongly confirmed. Other theoretical analyses of Exps. 5 and 6 may be equally supported by the data and this would inevitably weaken the significance of even this limited amount of confirmation. The additional information furnished by Exps. 5 and 6 provides grounds for testing Luria's theory against the alternative approach already briefly developed in Chap. 2. This alternative approach stresses information processing capacity limitations, along with more conventional conditioning processes, and dispenses with the idea of the regulatory function of language. It will now be developed in more detail.

The Capacity Theory

Suppose first that the implicit verbal response 'red' has been conditioned to the appearance of red objects such as the red light signals used in the experiments. The production, as a requirement of the experiment, of the response 'blue' to a red signal would require the application of an extra, internal transformation having the form, 'change the response "red" to the response "blue"'. This transformation need not, of course, be enacted consciously; it is perhaps best imagined as embedded in whatever physiological mechanisms subserve linguistic processes. The findings

of Crossman (1956) make it plausible to assume that this
extra transformation uses up channel capacity which
would not be used up if the overt verbal response was a
simple augmentation of the implicit response.   (The
general argument for this conclusion is that the extra
transformation will require an extra step in the
computation of the response, and the more elaborated the
'code' connecting stimulus and response the more it will
need protecting against random neural 'noise'.   Both
the computation and the rechecking needed for protection
will require channel capacity.)   If the task of
pressing a red button to a red signal is now conjoined
with the requirement to say 'blue' to the signal, then
it will not be performed as efficiently as if it were
conjoined with the requirement merely to say 'red'.
This is because the motor task will have less channel
capacity at its disposal, providing, of course, that the
$\underline{S}$ is working near to the limits of his capacity.

The capacity requirements of the different facets
of the task can be designated in the following way:
let x = the capacity requirement of the motor task of
pressing a button which is the same colour as the light.
Let dx = the increment in capacity requirements for
pressing the button opposite in colour to the light.
The quantities y and dy can represent the corresponding
capacity requirements for the overt verbal labelling
task.

An analysis of the various conditions of Exps. 5

and 6 according to this theory is set out in Table 28, below. The capacity requirements are represented qualitatively in Fig. 39 (a) and the implications for the performance of the motor task are set out in (b).

TABLE 28

Capacity Requirements for the Task
of Experiments 5 and 6

Experimental Conditions	Capacity Requirements		Total
	Motor Responses	Verbal Responses	
1	x	y	x + y
2	x	y + dy	x + y + dy
3	x + dx	y	x + y + dx
4	x + dx	y + dy	x + y + dx + dy

(Comparison with Table 7 may be helpful. N.B. dx, dy need not be small.)

Further Discussion of Hypothesis 1

Luria's theory groups together conditions 2 and 3 in which the motor and verbal responses are at odds with one another. It predicts that they will be more diffi- cult than conditions 1 and 4, which are also grouped together because here the motor and verbal responses are
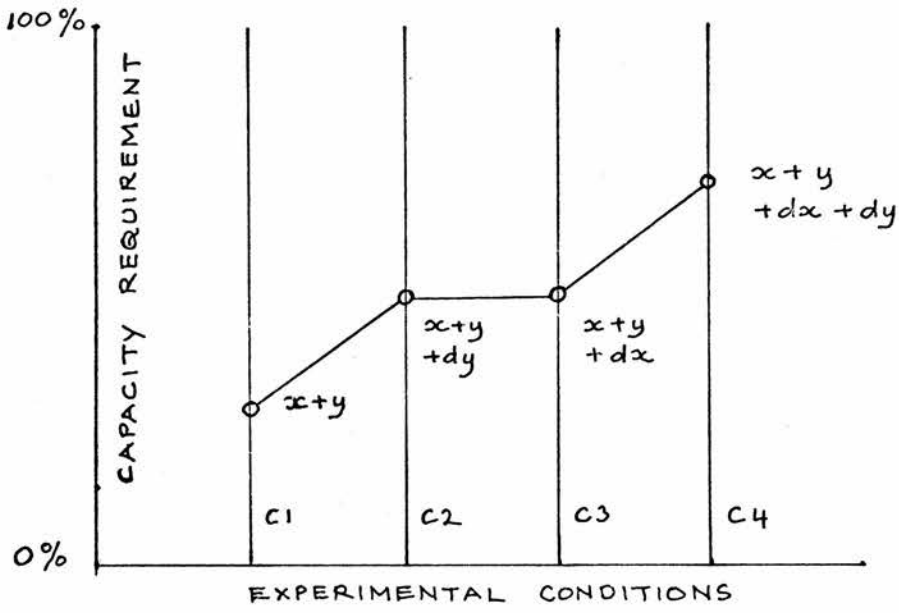
QUALITATIVE REPRESENTATION OF CAPACITY REQUIREMENTS
IN THE FOUR CONDITIONS OF EXPERIMENTS 5 AND 6

FIG. 39 (a)
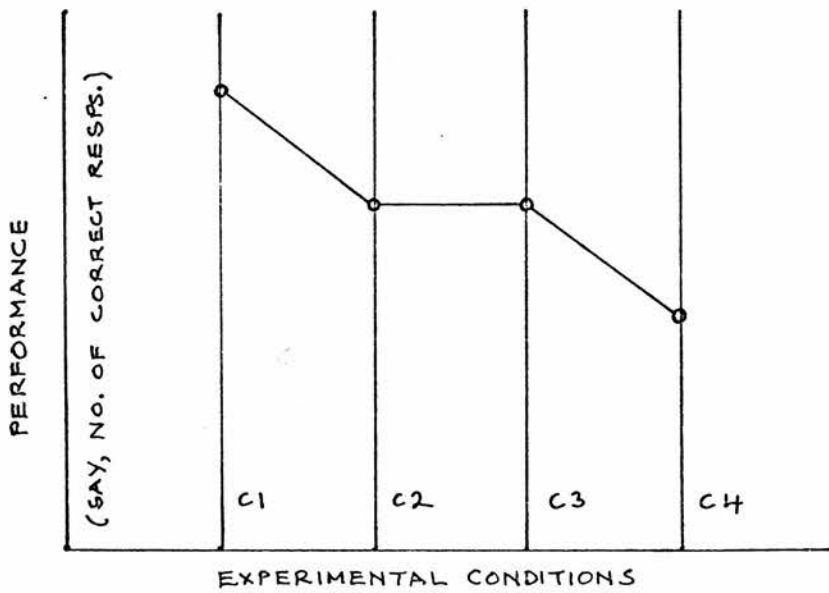
QUALITATIVE PREDICTION OF PERFORMANCE IN
THE FOUR CONDITIONS OF EXPERIMENTS 5 AND 6

FIG. 39 (b)

compatible. The Capacity theory in its simple form
also groups together conditions 2 and 3, and like
Luria's theory predicts that they will be more difficult
than condition 1 (see Fig. 39).

Sufficient data is at hand to reveal that both
theories, as they stand, are inadequate on the points
above on which they agree. This is because conditions
2 and 3 are significantly different from one another in
both the number of correct responses and the number of
intrusions. What sort of modifications are required of
the two theories? Luria's theory will have to introduce
assumptions which stress other factors apart from the
incompatibility of the verbal and motor systems. Such
assumptions would have to introduce an asymmetry in the
Luria analysis of conditions 2 and 3. For the Capacity
theory a similar asymmetry is required and could be
achieved by discarding the simplifying assumption that
the extra capacity requirements caused by S-R incompati-
bility is the same for the verbal and motor systems,
viz. that $dx = dy$.

In another respect, though, the Capacity theory
represents an advance because it highlights a source of
weakness in Luria's predictions. Both the Capacity
theory and Luria's theory correctly predict that
condition 1 should be more easily performed than either
of the more complicated incompatible conditions, 2 and 3.
But the Luria theory goes further and permits the
grouping together of conditions 1 and 4, as in

Hypothesis 1.   The limited success of this hypothesis almost certainly arises because condition 4 does not behave in the manner predicted by Luria, e.g. see Fig. 27.   What is required is a theory which provides reasons for separating condition 1 from condition 4.

Hypothesis concerning Condition 4

Fig. 39 shows that the Capacity theory predicts that condition 4 should be the most taxing one to perform.   This distinguishes the predictions of the two theories, because for Luria condition 4 should not be the most taxing.   For Luria the main determinant of performance should be the compatibility of the motor and verbal responses.   S-R compatibility should only be of minor importance, so conditions 1 and 4 should produce comparable results, because in both the verbal and motor responses are compatible with one another.

These further predictions can now be compared with the experimental data.   First the qualitative theoretical graphs (Fig. 39) can be compared with the graphs showing the mean number of correct responses, i.e. Figs. 27 and 33.   This suggests that only the low-load group corresponds to the predictions of the Capacity theory.   (The high-load group does not accord well with either theory on this test.)

A more accurate picture emerges from the statistical data relating the crucial condition 4 to the other conditions.   Taking the low-load group first: in every

case but one, where there is a significant difference
between condition 4 and conditions 2 and 3, this is in
the direction predicted by the Capacity theory.   That
is, the correct motor responses in condition 4 are fewer,
and missing and intrusive responses greater in number,
than in conditions 2 and 3.   (The one exception is that
the number of missed motor responses by female Ss is
significantly greater in condition 2 than in condition
4.)   In general, though, the correspondence between the
theoretical motor performance graph given by the
Capacity theory and the graph of observed correct motor
scores for the low-load group is borne out.

Moving now to the high-load group the trend seems
to be reversed.   Where there is a significant
difference between conditions 4 and 2 or 3 - and it only
occurs for the missing responses - it is in the
direction predicted by Luria.   Thus condition 4
produces fewer missing responses than conditions 2 or 3.

The question at issue between the two theories can
be pressed further by looking directly at the relation-
ship between conditions 1 and 4.   For Luria these are
both compatible conditions and should therefore produce
very similar results, whereas for the Capacity theory
condition 4 should be much more taxing.   For the low-
load group all performance measures and all groupings of
Ss (with one exception) conform to the predictions of
the Capacity theory.   Condition 4 is significantly more
taxing than condition 1.   For the high-load group

exactly the same pattern of success for the Capacity
theory is revealed, only this time without a single
exception.   The one exception to the complete success of
the Capacity theory is that the female S̲s̲ in the low-load
group did not miss out significantly more motor responses
in condition 4 than condition 1.

Despite the successes of the Capacity theory, the
properties of condition 4 do not permit any clear choice
between this theory and Luria's.   The experimentally
established facts are more complicated than allowed for
by either theory.   The relationship between the two
incompatible conditions (2 and 3) and the compatible
condition 4 is not adequately accounted for by the
simple capacity schema of Table 28, as the data from the
high-load group concerning missing responses make clear.
On the other hand, the relationship between conditions 1
and 4 is much more clearly explained by the Capacity
theory than by Luria's.

Two more situations will now be examined in which
differing predictions can be drawn from the two theories.

Hypothesis concerning Condition 2

What predictions about the interaction of the
verbal and motor systems can be drawn from the Capacity
theory?

The most extreme result of competition for channel
capacity would be cessation of responses in one
modality.   Much more likely are (a) intermittent

stoppages, (b) reversion to stereotyped responses, such
as alternation or repetition, or (c) reversion to an
easier type of response, say a lapse from responses
which were incompatible with the stimulus situation to
ones which were compatible with it.   This last case
seems a highly probable strategy for reducing load.
Particularly important in the context of Exps. 5 and 6
is that <u>it would produce the appearance of one response
system dominating another.</u>   Strategy (a) and (b) would
afflict the verbal and motor systems equally, but
strategy (c) would afflict whichever modality is
incompatible with the stimuli.   The Capacity theory
thus has an explanation for certain cases of the
apparent dominance of one response system over another,
namely that it is an artefact, and that what is really
happening is that a response is reverting under pressure
to one <u>compatible with the stimuli</u>.

This analysis leads to the same prediction as
Luria's in condition 3.   In this condition it is the
motor responses which are not compatible with the
stimuli, though the verbal ones are.   Any reversion
would present the appearance of verbal domination.   In
condition 2, however, the reverse situation obtains.
Here the Capacity theory would predict the apparent
domination of the motor system over the verbal system,
deviating strikingly from Luria's theory.

These predictions will now be tested.   For the
combined male and female Ss in the low-load group there

is a significant difference between the number of verbal
and motor intrusions in condition 2. The direction of
the difference is that predicted by the Capacity theory
and opposite to that predicted by Luria. For the high-
load group there is no significant difference in the
number of verbal and motor intrusions in condition 2.
(But for the high-load group the marking convention for
the verbal responses may have minimised the number of
verbal intrusions and will be working against the
interests of the Capacity theory.) The outcome, then,
is that where there is a significant difference between
the scores the Capacity theory is well supported. That
is, there are more opposite verbal responses than
opposite motor responses in a situation in which the
motor responses are compatible with the stimuli but the
verbal responses are not. This suggests that the
Capacity theory is right in placing emphasis on S-R
relationships. The difficulty that Ss encounter in
condition 2 may be associated with deviating from the
response which is 'naturally' associated with the
stimuli, rather than because the responses run counter
to the verbal set.

The evidence that S-R compatibility is an important
variable is well illustrated by the graphs showing the
mean number of motor and verbal intrusions for the low-
load group. These reproduced below as Fig. 40. Here
the lower number of intrusions is associated with
whichever response modality is compatible with the
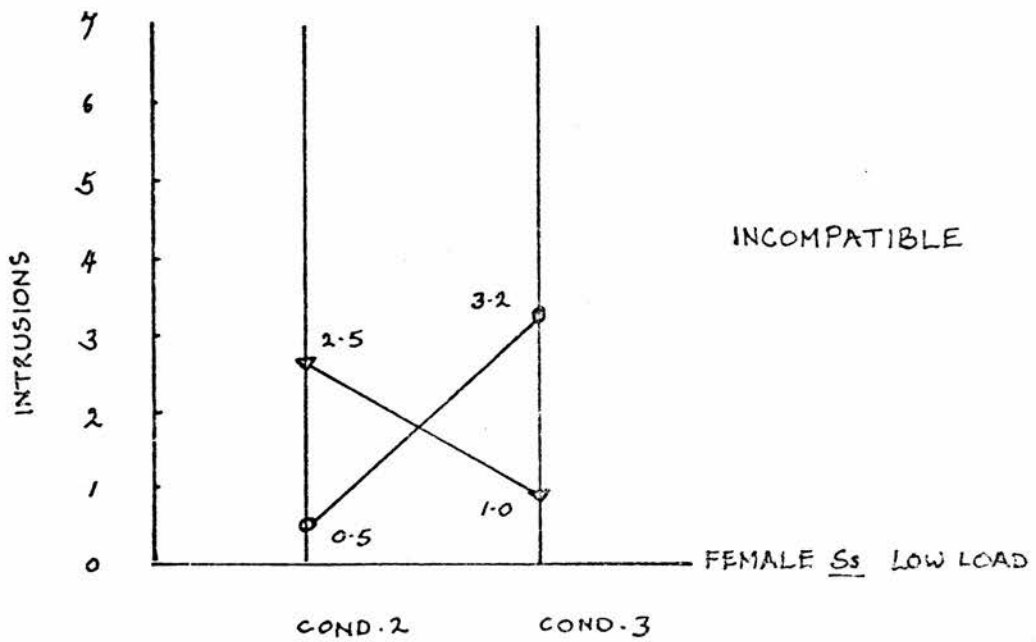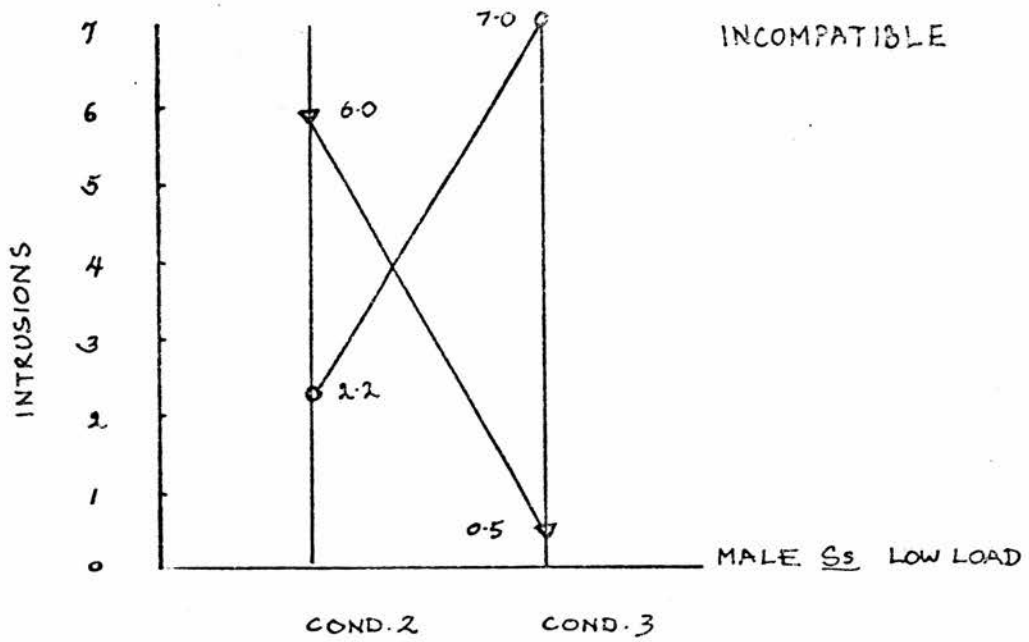
THE INFLUENCE OF STIMULUS-RESPONSE COMPATIBILITY
ON MOTOR AND VERBAL INTRUSIONS (DATA FROM EXP. 5)

FIG. 40

stimulus.   The differences shown in Fig. 40 are signi-
ficant when male and female $\underline{S}s$ are combined.   The out-
come of this test, then, favours the Capacity theory.

Further Discussion of Hypothesis 2

Luria's theory predicts that the total number of
motor intrusions in conditions 2 and 3, where the motor
and verbal systems are at odds, should be greater than
the total number of verbal intrusions.   The Capacity
theory predicts that in condition 2 the number of verbal
intrusions should be high and the number of motor
intrusions low.   For condition 3 it predicts the
opposite.   The total number of verbal and motor
intrusions should therefore be approximately the same if
the respective motor and verbal scores from these two
conditions are combined.   (This is assuming that the
verbal and motor systems react in the same way to
incompatibility with the stimulus, viz. $dx = dy$.)   This
prediction of the null hypothesis is better supported
than Luria's prediction if attention is restricted to
the low-load group: but it fails for the high-load group.

Summary

What emerges from this complicated pattern of
results?   The only simple thing that can be said is
that neither theory, at the moment, can cope with all
the data, though they both have their successes.   The
lengthy discussion has mapped out the area covered by

the two theories, exhibiting the points at which they
break down, and the ways in which they complement one
another.   A detailed grasp of the limitations of the
two theories is valuable because it provides the
specifications which will have to be satisfied by any
new theory in the field.   The discussion shows the
value that will attach to any successful synthesis of
the Luria and Capacity theories.   A simple form of
such a synthesis will be sketched in the next chapter.

CHAPTER IV

FURTHER DEVELOPMENT OF THE CAPACITY THEORY

The discussion of Exps. 5 and 6 has made it clear that
neither Luria's theory nor the Capacity theory, in their
present form, can account for all the experimental data.
At the very least a synthesis is required.   A simple
form of such a synthesis will now be sketched and
explored.   The attempt will be made to modify and
expand the Capacity theory in the light of Luria's theory
but without, if possible, explicitly adopting the hypo-
thesis that language regulates behaviour.

Both Luria's theory and the Capacity theory can be
considered as 'one-factor' theories in that they both
stress one single facet of the experimental situations
that they have been used to analyse.   The factor
stressed by Luria's theory is the compatibility of the
motor and verbal responses, i.e. R-R compatibility.
The factor stressed by the Capacity theory is S-R
compatibility, along with its implications in terms of
capacity requirements.   A synthesis of the Luria and
Capacity theories would be a two-factor theory making
allowance for both S-R and R-R compatibility.

Outlines of a Two-Factor Capacity Theory

The one-factor Capacity theory can be extended to
take account of some of the processes stressed by Luria
by the following modification: R-R incompatibility can

be viewed as simply another way in which a task is made
more difficult, hence requiring more channel capacity
for its proper execution. On this expanded basis
another table of capacity requirements for the
conditions of Exps. 5 and 6 can be constructed. The
procedure will be exactly the same as in the case of the
one-factor theory except that the experimental
conditions 2 and 3 will have an extra capacity require-
ment, dz, added to allow for the difficulty of R-R
incompatibility. This extra difficulty will be absent
from conditions 1 and 4. Let x = the capacity require-
ment of the motor task in its compatible form, and y =
the corresponding quantity for the verbal task. Let
dx and dy be the increments in capacity requirements
produced by S-R incompatibility. dz has already been
defined. Then, with the experimental conditions
numbered as in Table 7, we have:

TABLE 29

Capacity Requirements for the Task of
Experiments 5 and 6 on the Two-Factor Theory

Condition	Motor Task	Verbal Task	R-R Compati- bility	Total Capacity Requirement
1 Requirement	x	y	0	x + y
2 Requirement	x	y + dy	dz	x + y + dy + dz
3 Requirement	x + dx	y	dz	x + y + dx + dz
4 Requirement	x + dx	y + dy	0	x + y + dx + dy

Note: dx, dy and dz are not necessarily small quantities.

It is now necessary to impose some further
constraints on the size and relationships of the
quantities dx, dy and dz, in the above table, so that
some qualitative predictions can be drawn from the
theory.   To begin with, the experimental results so far
established strongly suggest that $dx \neq dy$, that is to
say, the added difficulty of producing responses
incompatible with the stimulus is not the same for the
verbal and motor systems.   Indeed, for the $\underline{Ss}$ of Exps.
5 and 6 the number of correct responses suggests that
$dx > dy$, i.e. the increment of difficulty is greater
when incompatible motor responses are demanded than
when incompatible verbal responses are required.
(This, in itself, is some evidence in favour of a Luria
picture because he maintains that the verbal system in
children is more 'mobile' and flexible than the motor
system.)

Having stated the relationship between dx and dy
the relative value of dz must be specified.   This is,
in effect, an answer to the question of how important is
the factor of R-R incompatibility.   Suppose first that
dz is small compared with dx and dy, that is, the effect
of R-R incompatibility is very small;   then, $dx > dy > dz$.
This entails a graph of capacity requirements looking
like that in Fig. 41 (a) below.   On the assumption that
$\underline{Ss}$ are working near to the limits of their capacity this
leads to the performance predictions of Fig. 41 (b).
(Clearly the assumption that dz is small would lead in

(a)

(b)
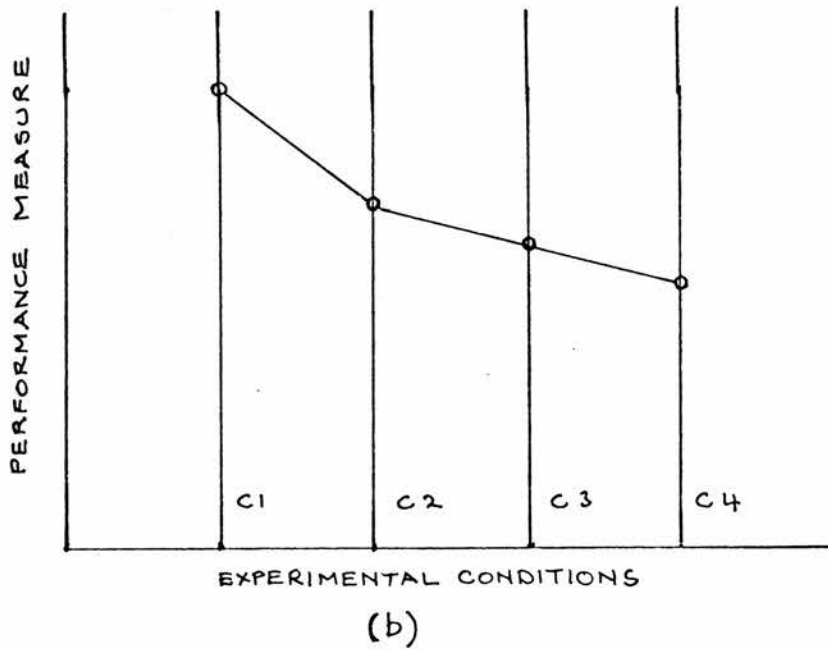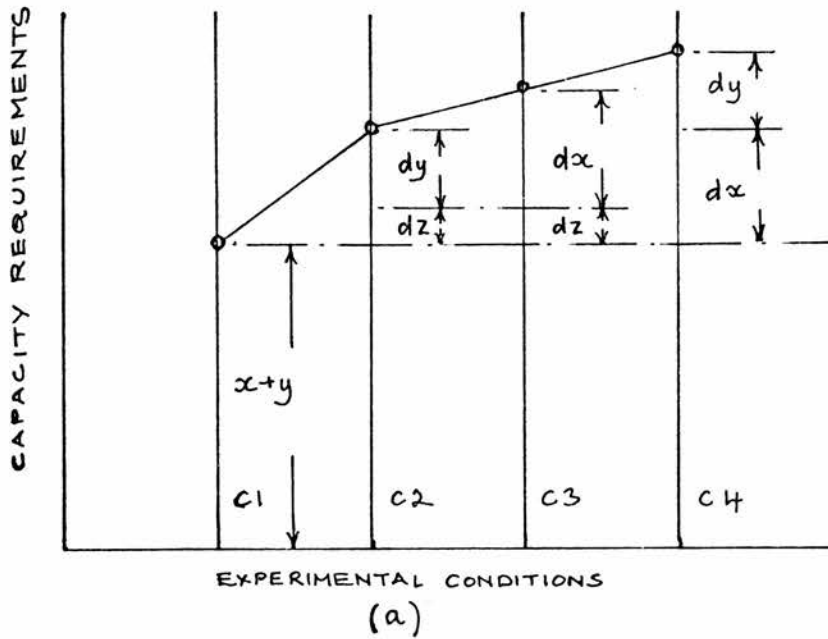
NOTE: ASSUMPTION, $dx > dy \gg dz$

CAPACITY REQUIREMENTS AND PERFORMANCE
PREDICTIONS OF THE TWO-FACTOR THEORY
ON THE ASSUMPTION THAT dz IS SMALL

FIG. 41

the limit to the one-factor Capacity theory which is a
limiting case of the two-factor theory.)

Quite a different situation obtains, though, if it
is assumed that dz is not small, but, say, on a par with
dx, the larger of the two increments of difficulty
caused by S-R incompatibility.   On this assumption a
different sort of graph results, as Fig. 42 (a) below
shows.   On this assumption the third condition is the
most taxing, and the second and fourth conditions very
similar.[*]

These hypothetical cases are only two out of an
indefinitely large number of possibilities that could be
imagined.   They do, though, have a special significance:
the forms of the graphs in (b) in the above figures
corresponds very closely to the graphs of the correct
motor responses that were obtained for the low and high-
load groups respectively in Exps. 5 and 6.   These
experimentally derived graphs are given below for
comparison with the theoretical curves.   (The graphs
below show the result for female Ss only, but the form
of the graphs for the male Ss is very similar.)

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[*] A numerical example may make this point clear.   Let
x + y = 50% of available capacity, let dx = 20%,
dy = 10%, and dz (= dx) = 20%.   Then condition 1
requires 50% capacity, condition 2 requires 80%,
condition 3 requires 90%, but condition 4 only
requires 80%.   These figures are computed by substi-
tuting the hypothetical numerical values into the
table of capacity requirements, Table 29.

CAPACITY REQUIREMENTS

CI   C2   C3   C4

$x+y$

dx

dy

dz

dz

dy

dx

EXPERIMENTAL CONDITIONS

(a)

PERFORMANCE MEASURE

CI   C2   C3   C4

EXPERIMENTAL CONDITIONS

(b)
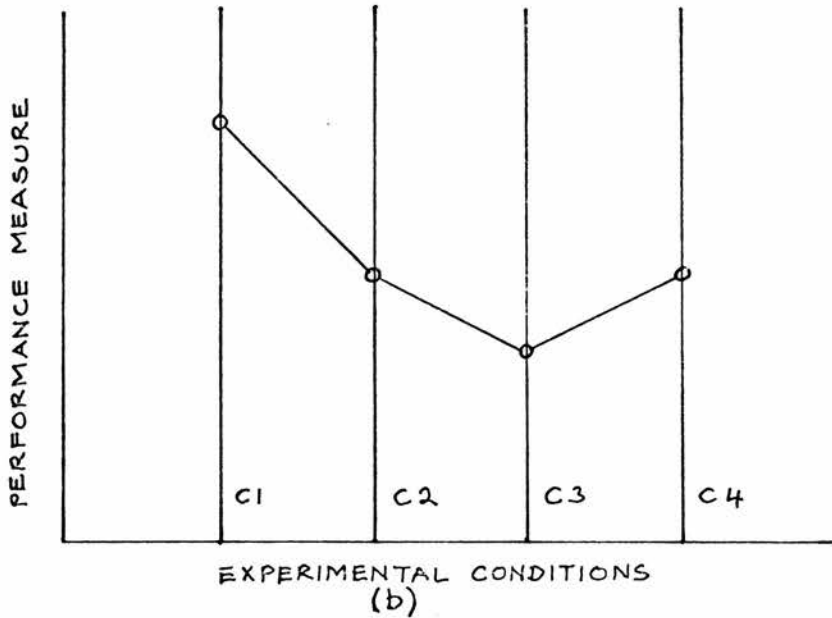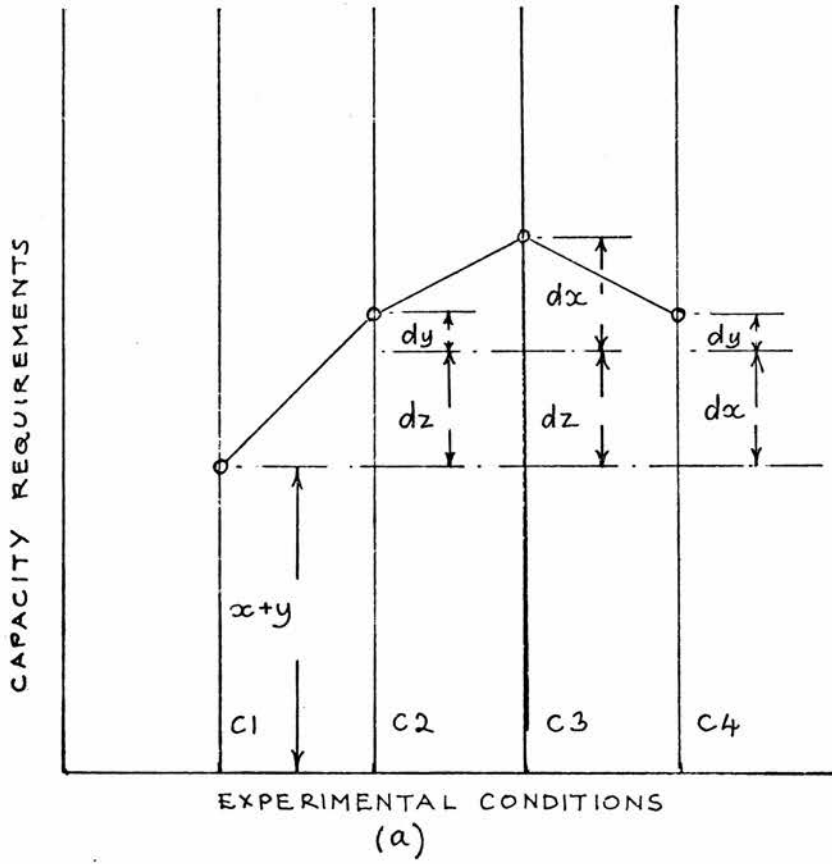
NOTE: ASSUMPTIONS, $dx > dy$, $dz = dx$ (approx.)

CAPACITY REQUIREMENTS AND PERFORMANCE
PREDICTIONS OF THE TWO-FACTOR THEORY
ON THE ASSUMPTION THAT dz IS LARGE

FIG. 42
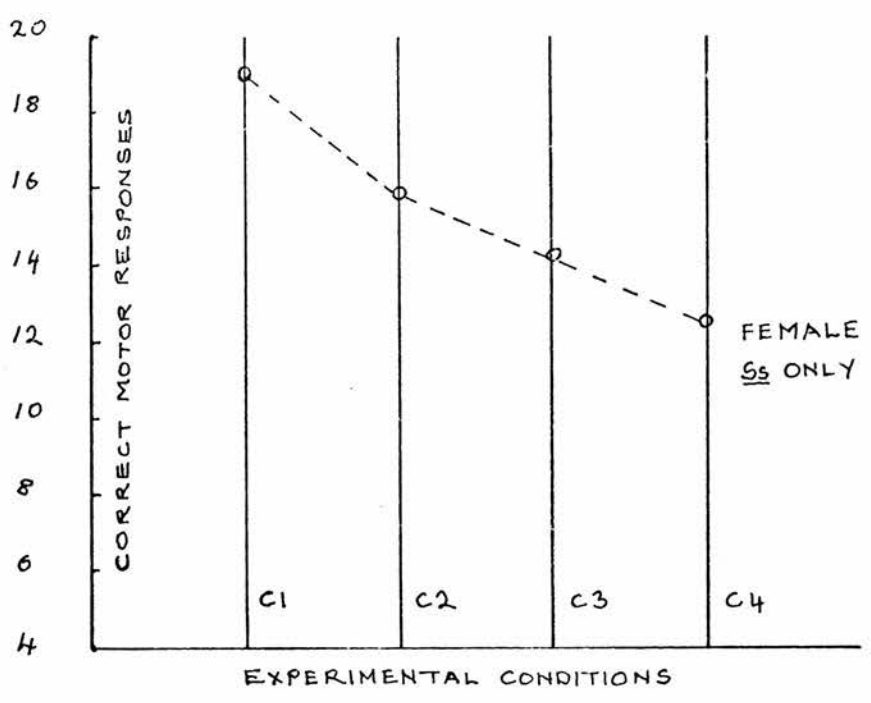
LOW-LOAD GROUP : COMPARE WITH FIG. 41(b)
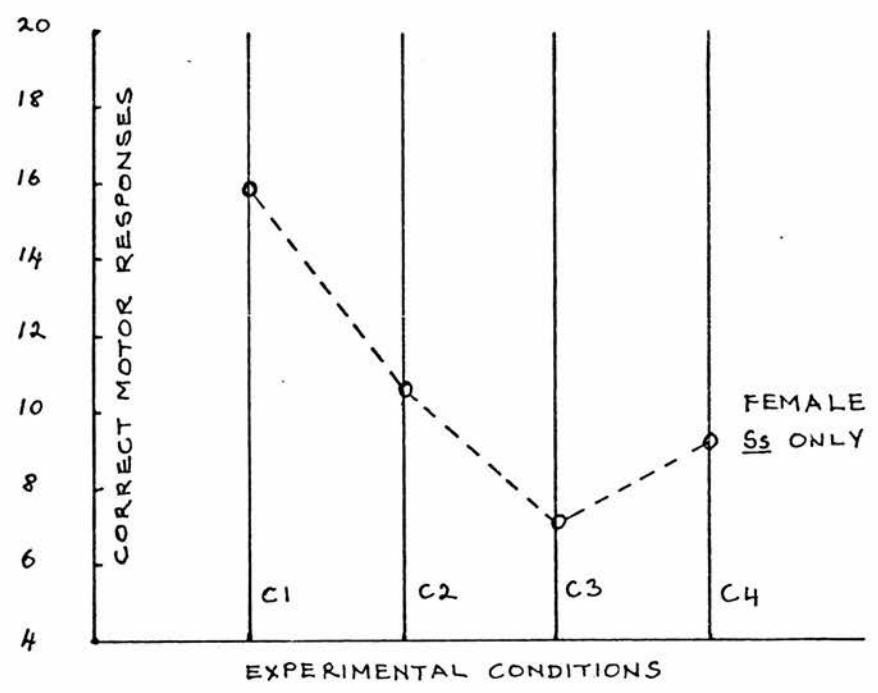
HIGH-LOAD GROUP : COMPARE WITH FIG. 42(b)

MEAN NUMBER OF CORRECT MOTOR RESPONSES IN
EXPERIMENTS 5 AND 6 SHOWING CURVES OF THE SAME
FORM AS THOSE PREDICTED BY THE TWO-FACTOR THEORY

FIG. 43

The two factor theory, then, already promises to
resolve one interesting anomaly in the experimental
results, namely the different forms of the curves for
the high- and low-load groups in the graphs giving the
number of correct motor responses.   It is difficult to
see how either one-factor theory could do this.   All
that is now required is to relate plausibly the
assumption that dz is small to the situation of the low-
load group, and the assumption that dz is large to the
situation in which the high-load group operate.

To do this it is necessary to expand the account so
far given of the psychological meaning of the parameter
dz, and show how it might vary in importance in
different experimental conditions.   First consider the
low-load group.   Under conditions of low-load it is
plausible to assume that the verbal and motor responses
are not in serious competition for resources in the
nervous system and can therefore be kept apart with
little mutual interference.   The 'overlap' of the
verbal and motor responses will be very small.   In
Fig. 44 below, let G represent a 'gate' the size of
which limits the total nervous resources shared by the
verbal and motor responses.   In (a) there is no overlap
at all.   This is a condition satisfactorily represented
by a one-factor Capacity theory.   In (b) there is an
overlap.   This forced sharing of resources with its
consequent possibilities for interference will provide
the conditions under which the factor dz becomes
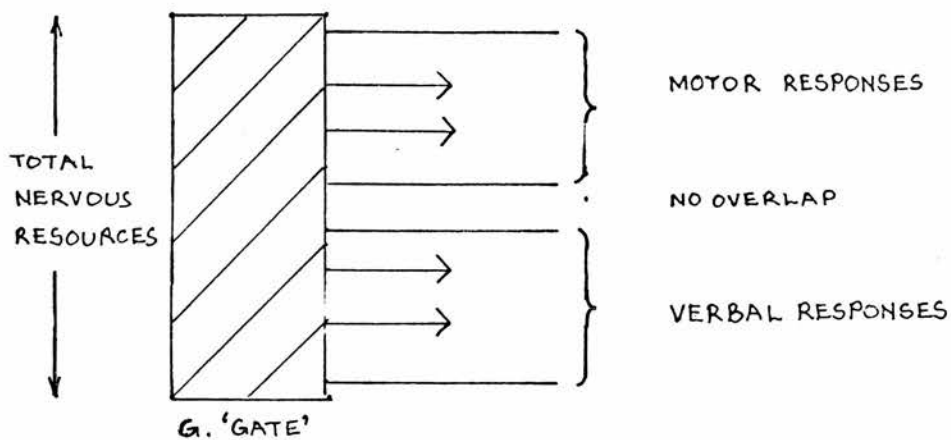
(a) NO OVERLAP, $dz = 0$
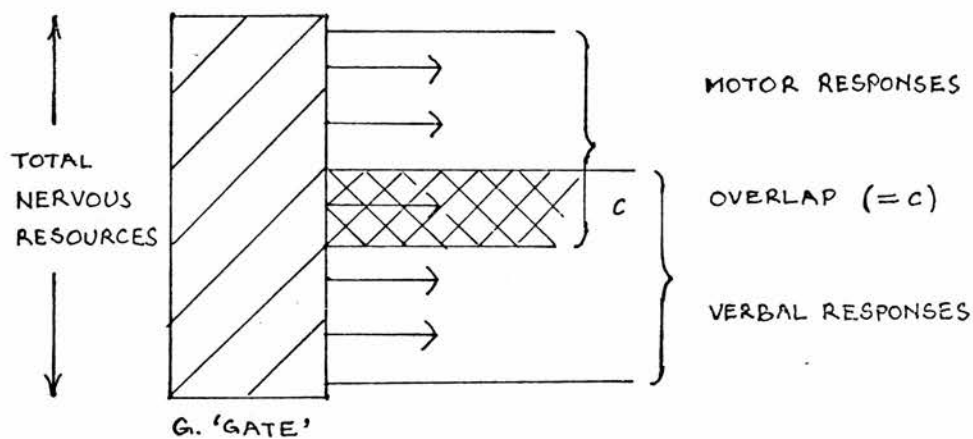
(b) OVERLAP, $dz > 0$, $dz \propto c$.

THE ALLOCATION OF RESOURCES BETWEEN
THE MOTOR AND VERBAL RESPONSES IN
HIGH AND LOW LOAD CONDITIONS

FIG. 44

important.   When the rate at which decisions have to be
taken is increased the amount of overlap will increase,
and the relation between the response modalities may
become crucial.   If the two response outputs have a
similar structure it is plausible to imagine them
running in parallel with little or no interference.
They may even share facilities in the nervous system, as
people going the same route can share a taxi.   However,
responses having different structures, requiring
different computations and transformations will not be
able to co-exist in the area of overlap;   indeed their
presence will ensure that the area of overlap will be
one of confusion resulting in missed or erroneous
responses.   Consequently the size of the effect
produced by the dz factor will vary with the size of the
area of overlap, that is, with the degree of difficulty
of the task.   This analysis, then, justifies
associating the condition in which dz is given a small
value with the low-load group, and the condition in
which dz is given a large value with the high-load group.[*]

So far the only response measure that has been
considered is the number of correct motor responses.
Attention will now be turned on the remaining two
measures.   If the graph predicting the number of
correct responses can be treated as a simple mirror-image

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[*] Care has been taken not to represent G as the total
capacity available for responses.   This would require
interpreting dz, the area of overlap, as a demand in
excess of 100% capacity, and this is not implied in
the original definition of the term.

of the capacity requirement graph (i.e. the higher the
capacity requirement the lower the number of correct
responses) then should not the missing and intrusive
response scores both simply have the same form as the
capacity graph (i.e. the more capacity is required the
more missing and intrusive responses there should be)?
Unfortunately this assumption would be quite arbitrary
because there is no reason a priori why the two sorts of
error should have the same pattern across the different
experimental conditions.   What is ideally required is
some theory about the nature of the errors so that
predictions can be made about the form of the graphs.
However, lacking any such theory resort must be had to
the simple and arbitrary assumption that the error
curves both follow the capacity curve.   This assumption,
incidentally, has been made implicitly throughout the
previous discussions of Exps. 5 and 6.   The consequences
of this assumption will now be examined.

Missing Motor Responses

For the high load group there are fairly large
numbers of missing responses and these do indeed closely
follow the same form as the capacity requirements.
That is to say that the number of missing responses
rises across conditions 1, 2 and 3 at which it is at its
peak.   The number then declines in condition 4 to
approximately the same number as in condition 2.   The
graphs of both the male and female Ss taken separately

have this form.   The simple assumption is thus borne
out for the high-load group, but it fails when tested
against the low-load group.   Here the graph of the
number of missing responses does not follow a mono-
tonically rising curve as it should do if it were
following the capacity requirement curve for this group.
The number of missing responses for the low-load group,
though, is on average very low indeed, so it is perhaps
not surprising that no trend can be discerned.

Opposite or Intrusive Motor Responses

Both the high- and the low-load groups present a
picture of steadily increasing numbers of opposite motor
responses across conditions 1 to 4.   This form of graph
is correct for the low-load group but not (on the simple
assumptions being made) for the high-load group.

It looks superficially as if the low-load group
behave as predicted, but the result has an anomalous
feature which deserves closer examination.   This is
that the mean numbers of opposite responses is higher
for the low-load group than for the high-load group.
For the high-load group the mean number of opposite
responses rises to around 5 (for male Ss), for the low-
load group it rises to around 9 (again for male Ss).
This is odd because errors of intrusion are presumably
caused by the overlapping of the verbal and motor
channels, a feature that should be associated with the
high- but not the low-load group.   Examination of the

raw data explains the anomaly, the cause of which is disguised by looking only at mean values. The low-load group consists mainly of Ss with very low opposite response scores, but a few Ss made a very high number of opposite responses. It is these Ss who are responsible for the high average scores. What seems to be happening is that a number of low-load Ss change the 'rule' according to which they make their responses and proceed systematically to produce the opposite of what is required of them. The error lies in the initial 'set' of the S, in the task that he chooses to do, rather than in any difficulty in executing the assigned task. Why should this happen more often to the low-load group rather than the high-load group? A possible explanation concerns the much longer gaps between stimuli and the longer gap before the beginning of the experimental runs. These gaps provide time for the rehearsal or attempted rehearsal of instructions, and it may be in this process that error creeps in.

This suggestion, though made on an ad hoc basis, is one very small step towards producing a theory of the mechanisms underlying the different sorts of errors, a requirement whose importance was stressed earlier. In this case, though, it must be noted that the mechanism invoked, namely the initial 'set' governing the responses, is a quite different sort of process to one which could be integrated into either Luria's theory or a one or two-factor Capacity theory. These theories ideally

require explanations of errors purely in terms of the
ongoing processes of self-instruction or response
organisation which are at work during the production of
a sequence of responses.   An explanation in terms of
'set' is invoking extra and different mechanisms which
come into play before the stages dealt with by the Luria
or Capacity theories.

The fact that there may be two rather different
processes at work producing opposite responses means
that the monotonically increasing graph of numbers of
opposite responses for the low-load group may be some-
thing of an artefact.   It should not therefore really
count as a success for the simplified hypothesis
concerning error prediction that is being examined.
The outcome, then, is that the distribution across the
experimental conditions of the opposite motor response
scores cannot be explained, either for the high- or the
low-load groups.

The three out of four failures to explain the error
scores need not, though, be considered particularly
dangerous for the Capacity theory.   The failures in fact
occur in an area in which the theory is silent rather
than in an area in which it makes specific predictions.
The one prediction that did succeed followed from an
extremely simple and rather arbitrary extension of the
theory and there is plenty of room for adjustment.

Most of the issues dealt with so far concern the
relation of the two-factor theory to the data connected

with Hypothesis 1 of Exps. 5 and 6. To conclude the
discussion of the two-factor theory it will be related
to data concerning Hypothesis 2. The two-factor theory
in effect reproduces the predictions of the one-factor
Capacity theory in this area. In other words it
assumes that the motor system will appear to dominate
the verbal system in condition 2 and that the verbal
system will appear to dominate the motor system in
condition 3. The real process will be the lapse into
compatibility of whichever modality is incompatible with
the stimuli. The reason why the two-factor theory is
the same here as the one-factor Capacity theory is
because, although it accepts the interference of the
verbal and motor systems, it contains no postulate
concerning the genuine domination of one response system
over another when there is competition. It was for
this reason that the two-factor theory was introduced as
a synthesis which only took account of _some_ of the
processes stressed by Luria. Because of this limitation
the two-factor theory as it stands will necessarily fail
to explain the apparent fact that the high-load Ss do
show evidence that, when conditions 2 and 3 are combined,
the number of motor intrusions is greater than the
number of verbal intrusions.* It appears that the two-
factor theory may need supplementing with a genuine

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* It is difficult to know, though, how much weight to
place on this result because here Luria's theory is
aided by the scoring convention that was adopted for
the verbal responses. So it is possible that this
result is an artefact.

Luria component which comes into play to regulate the
interaction of the verbal and motor systems and which
postulates that the verbal will dominate the motor.
If this is so, then the efforts to account for the
experimental data without recourse to the regulatory
postulate will have failed. The reliability of the
experimental techniques used to record the number,
nature and timing of the verbal responses is thus of
quite crucial importance. This provides a strong
reason for repeating certain aspects of the previous
experiment, in particular the two incompatible
conditions (2 and 3) using different and more objective
means of recording the verbal responses. Only then
will it be clear if there are unavoidable grounds for
retaining the postulate that language is exercising a
regulatory function in the conditions being studied.

EXPERIMENT 7.   A COMPARISON OF VERBAL AND MOTOR ERRORS
IN THE TASK OF EXPERIMENT 6

The purpose of this experiment is to provide an
accurate measure of the number of motor and verbal
errors in a task where the verbal response to a stimulus
is at odds with the motor output, e.g. in pressing one
of a pair of response keys but verbalising the label for
the other. The previous experiment has left this issue
in some doubt due to difficulty in recording the timing
of the verbal responses. Accurate data on this issue
is necessary because it will determine whether, in the

last analysis, the existence of processes of verbal regulation must be accepted. Because of the limited focus of the present experiment only the two relevant experimental conditions will be extracted from the previous experimental design.

Hypothesis

Where the verbal system and the motor system are in competition (e.g. when pressing the blue button but saying 'red' in the task of Exp. 6) then the verbal system will predominate over the motor system and Ss will tend to press the wrong button more frequently than they will say the wrong word. (The alternative hypotheses derived from the Capacity theory will be introduced in the discussion section.)

Subjects

The 40 Ss were the pupils of the Milton House Primary School, Edinburgh, and the South Bridge Primary School, Edinburgh. Half of the Ss were from each school with equal numbers of boys and girls in each sample. No Ss had sensory-motor defects and none had to be eliminated through failure to cooperate. The Ss were chosen by simply working down the class registers. The details are given in Table 30 below.

TABLE 30

Details of the Subjects of Experiment 7

Subject Group	Number	Mean Age in Months	S.D.	Mean Peabody Test Score[*]	S.D.
Male	20	78.8	5.1	60.2	8.8
Female	20	79.8	2.9	61.3	11.1

[*] Raw Score.   See Appendix I.

Experimental Design

The design is essentially a truncated version of that used in Exp. 6.   The Ss were presented with the same sequence of red and blue light signals as in the previous experiment, and in one condition they had to press a button the same colour as the light but say the name of the other colour.   In the other condition the verbal response corresponded to the colour of the signal, and it was the motor response which was incompatible with the stimulus.   These conditions will be referred to from now on as condition 2 and condition 3 respectively, as in Exp. 6.   All Ss were given both conditions, half in one order, half in the other, with equal numbers of boys and girls in each group.

Apparatus

This was essentially the same as in Exp. 6, but with an important modification.   In Exp. 6 Ss had their verbal responses recorded by E.   In this case the

verbal responses were recorded by a tape recorder.
This alone would not have solved the problem of
correlating the verbal and motor responses.   But as
well as this - for reasons to be made clear - the micro-
phone was fastened to the front of the S-R unit.   (This
meant that the microphone was directly facing the S at a
little below chest height as he sat with the S-R unit on
a table in front of him.   Pilot studies had shown that
with the microphone in this position no special
instructions had to be given to the S to speak into it,
other than the usual requirement not to whisper, a fault
which, if it occurred, was eliminated in pretraining.)

The result of attaching the microphone to the front
of the S-R unit was that it recorded both the S's verbal
responses and also picked up, through the casing, the
click of the buttons being pressed.   It was then
possible to correlate the clicks with the pen recording
of the button presses, which, of course, indicated the
difference between a red and blue press.   In this way
the timing and position of the verbal responses could be
accurately included in the graphic record of the motor
responses and the different sorts of error determined by
inspection.   On the few occasions when it was difficult
to establish the order of the clicks and the words, the
tape was played through at a slower speed and the
problem resolved.   Accurate recording of the verbal
responses could now be achieved and the bias of the
scoring convention that had to be adopted in Exp. 6 was
eliminated.

Procedure

This was exactly the same as in the previous experiment, except that only the two R-R incompatible conditions were used.

Results

The most important result concerns the relative number of verbal and motor intrusions. The data bearing on this will be presented both for the original group of 40 Ss and also for two specially selected subgroups.

1) Comparison of the total number of verbal and motor intrusions when the scores of both experimental conditions are combined. The tables below show the result of applying a Wilcoxon matched-pairs test to see if there is a significant difference between the numbers of verbal and motor intrusions.

TABLE 31

Comparison of Motor and Verbal Intrusions when Conditions 2 and 3 of Experiment 7 are Combined

Subjects	Conditions 2 and 3 Combined
Male	$T = 82.5$ (NS) $N = 19$
Female	$T = 58$ (NS) $N = 15$
Combined	$T = 286$ (NS) $N = 34$

2) Comparison of the number of intrusive motor and verbal responses within each of the two experimental conditions treated separately. The mean numbers of intrusive motor and verbal responses are given in Figs. 45 and 46.

TABLE 32

Comparison of Motor and Verbal Intrusions within Conditions 2 and 3 of Experiment 7

Subjects	Condition 2	Condition 3
Male	$T = 52.5$ (NS)	$T = 31$ (NS)
	$N = 16$	$N = 14$
Female	$T = 41.5$ (NS)	$T = 8$ (NS)
	$N = 15$	$N = 9$
Combined	$T = 184$ (NS)	$T = 69^*$
	$N = 31$	$N = 23$

[*] Sig. at .05 level on a two-tailed Wilcoxon Test.

3) The same comparisons as above will now be made with a selected subgroup of 'high-scorers'. First, though, the selection of the subgroup will be described. The idea was to filter out those Ss who were not maintaining the required motor set and who lapsed into making very few correct motor responses. On this basis only those Ss were retained for consideration who scored more than 5/20 correct motor responses on both of the experimental runs. Some of these Ss were then eliminated in order to leave a subgroup which was balanced in terms of the order of presentation of the experimental conditions. This was done by sorting the Ss into two groups depending

on the order of presentation of the experimental
conditions and then selecting from the larger group Ss
who matched those in the smaller group in terms of the
mean number of correct motor responses.   Where there
was more than one such S to choose from that one was
selected whose performance was least favourable to the
Capacity theory's predictions about the number of motor
and verbal intrusions in condition 2.   This left a sub-
group of high scorers of N = 12.   No attempt was made
to balance the sex ratio of the group in which there
were twice as many female as male Ss.

The mean number of motor and verbal intrusions in
the two experimental conditions for the high scores are
given in Fig. 47.

TABLE 33

Comparison of Motor and Verbal Intrusions
for the High Scorers in Experiment 7

Subjects	Condition 2	Condition 3
Selected Subgroup of High Scorers	$T = 2.5^{*}$ $N = 9$	$T = 10.5$ (NS) $N = 7$

Conditions 2 and 3 Combined
$T = 19$ (NS)
$N = 11$

* Sig. at .02 level on a two-tailed Wilcoxon Test.

4)   Another issue which will be considered in the
discussion section concerns the tendencies of Ss to
ignore one response channel in favour of the other, e.g.
devoting themselves to giving correct motor responses at
the expense of correct verbal responses.   One plausible
measure of such bias is the number of responses which
are missed out in the respective response channels.   On
this measure missing out equal numbers of motor and
verbal responses would suggest equal allocation of
capacity.   (The limitations of this assumption will be
mentioned later.)   Figs. 48 and 49 show the number of
missed motor and verbal responses for each S in
conditions 2 and 3.   Let those Ss who miss out equal
numbers of motor and verbal responses in any one of the
conditions be called the 'unbiased group' for that
condition (these groups will not necessarily be the same
for the two conditions).   Inspection of the graphs
shows that by a fortunate chance both the unbiased group
for condition 2 (N = 32) and the unbiased group for
condition 3 (N = 26) are balanced for the order of
presentation of experimental conditions.   Table 34
compares the number of verbal and motor intrusions in
the two experimental conditions for the appropriate
unbiased groups.   Fig. 50 shows the mean number of
such intrusions in the two conditions.   The point of
selecting unbiased groups will be explained in the
discussion section.

TABLE 34

Comparison of Motor and Verbal Intrusions
in Conditions 2 and 3 for the Unbiased Groups
in Experiment 7

Subjects	Comparison of number of motor and verbal intrusions (Wilcoxon Test)
Unbiased Group for Condition 2 $N = 32$	$T = 80.5$ $N = 24$ sig. at .05 level on a 2-tailed test
Unbiased Group for Condition 3 $N = 26$	$T = 26$ $N = 15$ ($z = 1.93$, $p < .054$ on a 2-tailed test)

The more general features of the performance of the Ss of Exp. 7 will now be examined in order to compare them with the trends that were seen in Exp. 6, and so that they may be related to the Capacity theory in the discussion section. The following data all applies to the original group of Ss not to the selected subgroups.

5) Comparison of numbers of correct, missing and intrusive responses in conditions 2 and 3. In the table below the scores of the male and female Ss have been combined. The graphs showing the mean numbers of the various motor and verbal scores are given in Figs. 51 to 56.

TABLE 35

Comparison of Motor and Verbal Responses

in Conditions 2 and 3 of Experiment 7

when Male and Female Subjects are Combined

Response Modality	Correct	Missing	Intrusive
Motor Responses	$T = 224.5^{*}$ $N = 38$	$T = 167.5^{**}$ $N = 36$	$T = 293.5$ (NS) $N = 37$
Verbal Responses	$T = 131^{+}$ $N = 39$	$T = 225.5$ (NS) $N = 36$	$T = 195.5$ (NS) $N = 35$

[**] Sig. at .01 level on a two-tailed Wilcoxon Test.

[*]   "   "   .05   "   "   "   "   "   "

[+]   "   "   .005   "   "   "   "   "   "
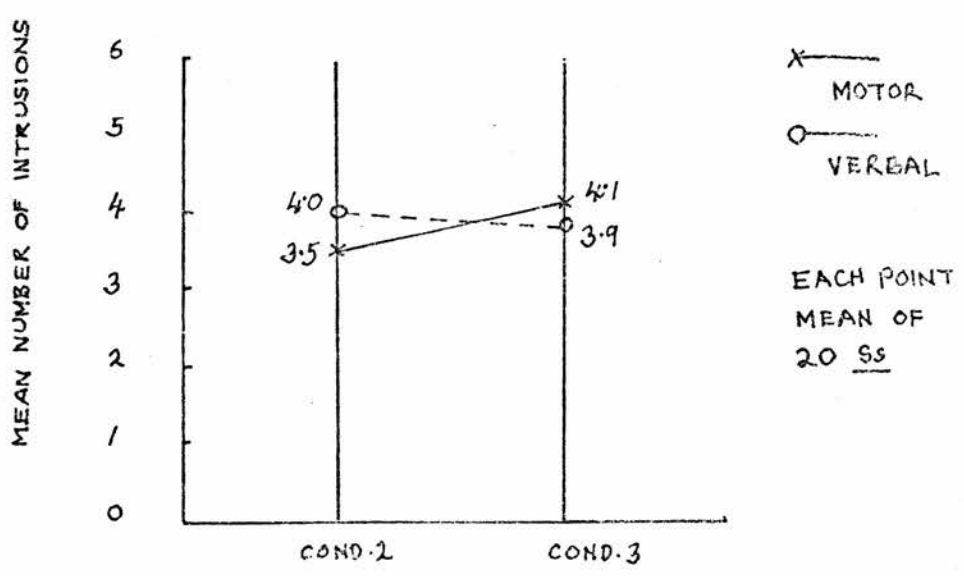
MEAN NUMBER OF MOTOR AND VERBAL
INTRUSIONS FOR MALE SUBJECTS

FIG. 45
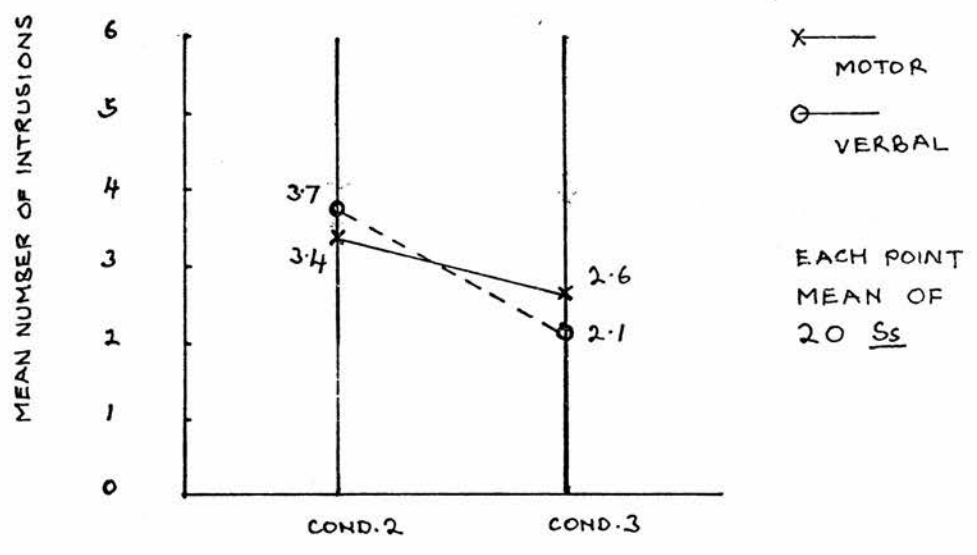
MEAN NUMBER OF MOTOR AND VERBAL
INTRUSIONS FOR FEMALE SUBJECTS

FIG. 46
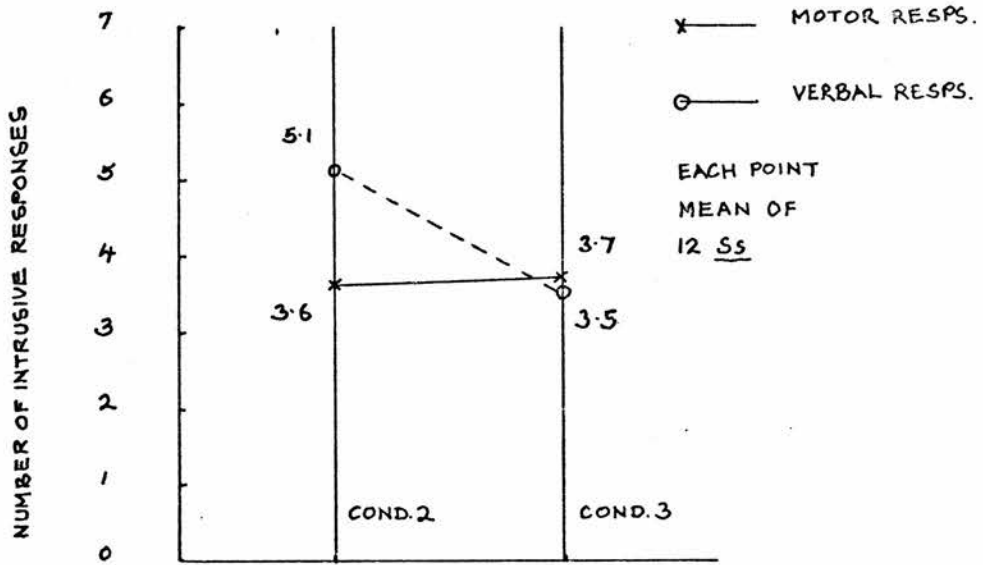
MEAN NUMBER OF MOTOR AND VERBAL
INTRUSIONS FOR THE HIGH SCORING SUBJECTS

FIG. 47
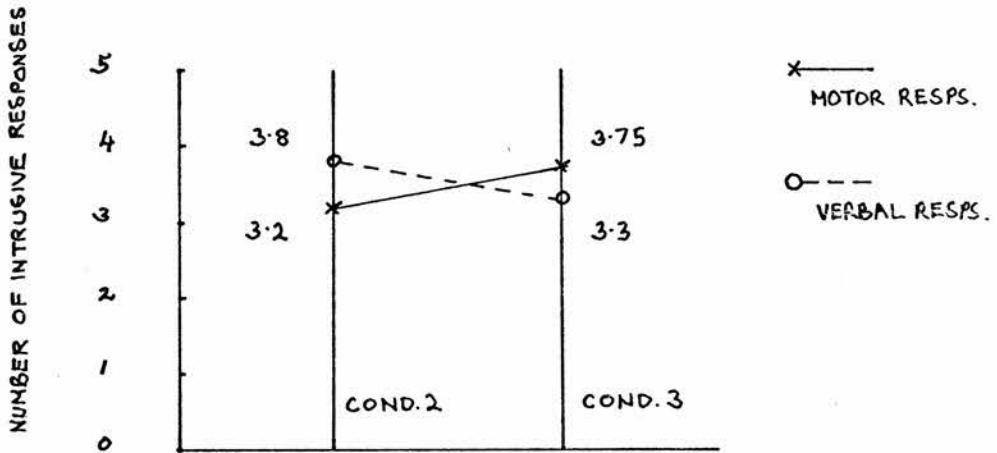
NOTE. IN COND. 2 EACH PT. IS THE MEAN OF THE 32 SS OF THE UNBIASED
GROUP FOR COND. 2. IN COND. 3 EACH PT. IS THE MEAN OF THE 26 SS
OF THE UNBIASED GROUP FOR COND. 3.

MEAN NUMBER OF MOTOR AND VERBAL
INTRUSIONS FOR THE UNBIASED GROUPS

FIG. 50

(FIGS. 48 AND 49 OVER PAGE)

MISSED MOTOR RESPONSES

MISSED VERBAL RESPONSES

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

● UNBIASED RESPONSES , ○ BIASED RESPONSES
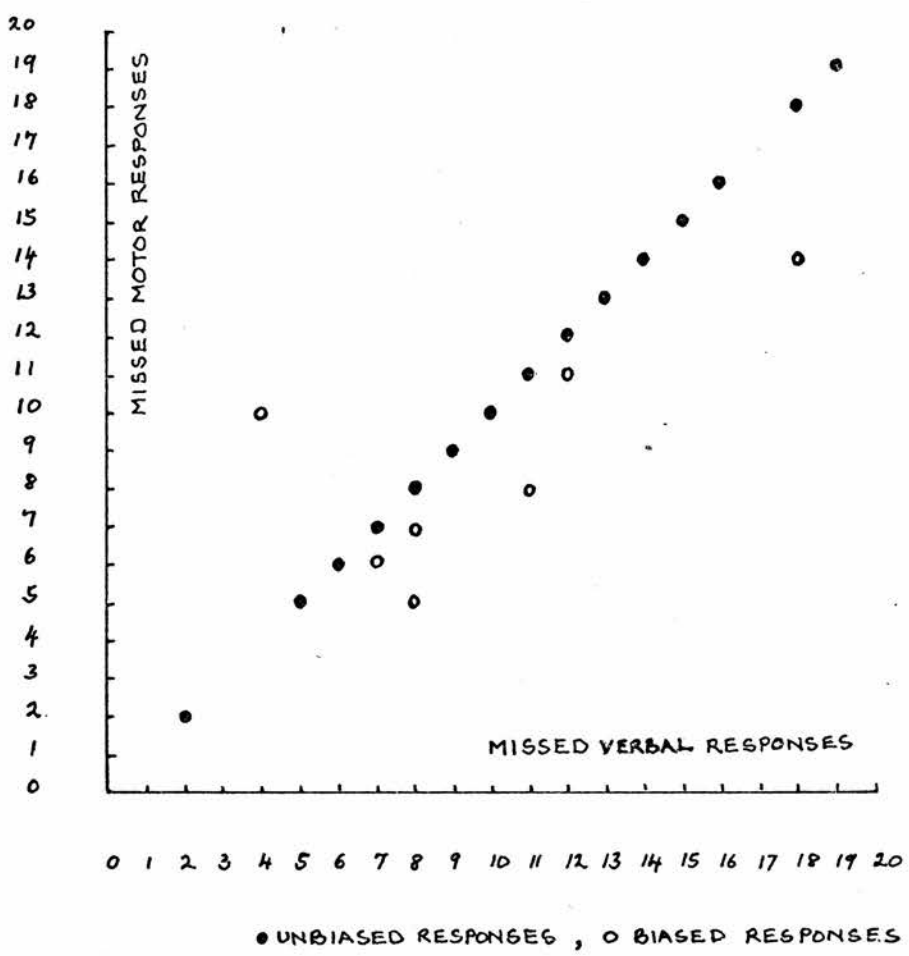
NO. OF MISSED MOTOR AND VERBAL RESPS.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
NO. OF Ss GIVEN COND. 2 FIRST	0	0	0	0	0	3	1	3	1	2	0	2	0	2	0	1	0	0	1	0
NO. OF Ss GIVEN COND. 3 FIRST	0	0	1	0	0	0	0	2	1	2	2	0	2	0	3	0	1	0	1	1

ORDER OF PRESENTATION OF CONDITIONS FOR UNBIASED GROUP

RELATION BETWEEN THE NUMBER OF MISSED
MOTOR AND VERBAL RESPONSES IN CONDITION 2

FIG. 48

MISSED MOTOR RESPONSES

MISSED VERBAL RESPONSES

● UNBIASED RESPONSES   O BIASED RESPONSES
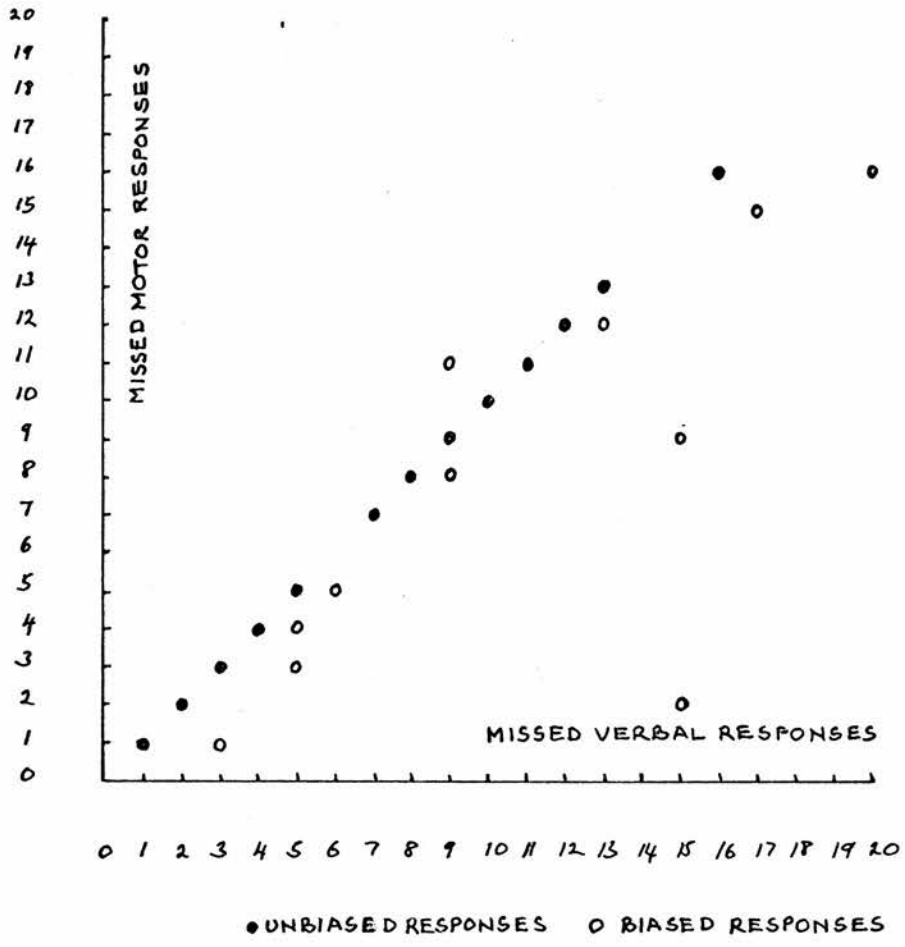
NO. OF MISSED MOTOR AND VERBAL RESPS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NO. OF Ss GIVEN COND. 2 FIRST	0	1	2	2	0	0	0	1	0	1	4	2	0	0	0	0	0	0
NO. OF Ss GIVEN COND. 3 FIRST	1	0	1	0	1	0	1	1	1	3	0	2	1	0	0	1	0	0

ORDER OF PRESENTATION OF CONDITIONS FOR UNBIASED GROUP

RELATION BETWEEN THE NUMBER OF MISSED
MOTOR AND VERBAL RESPONSES IN CONDITION 3

FIG. 49
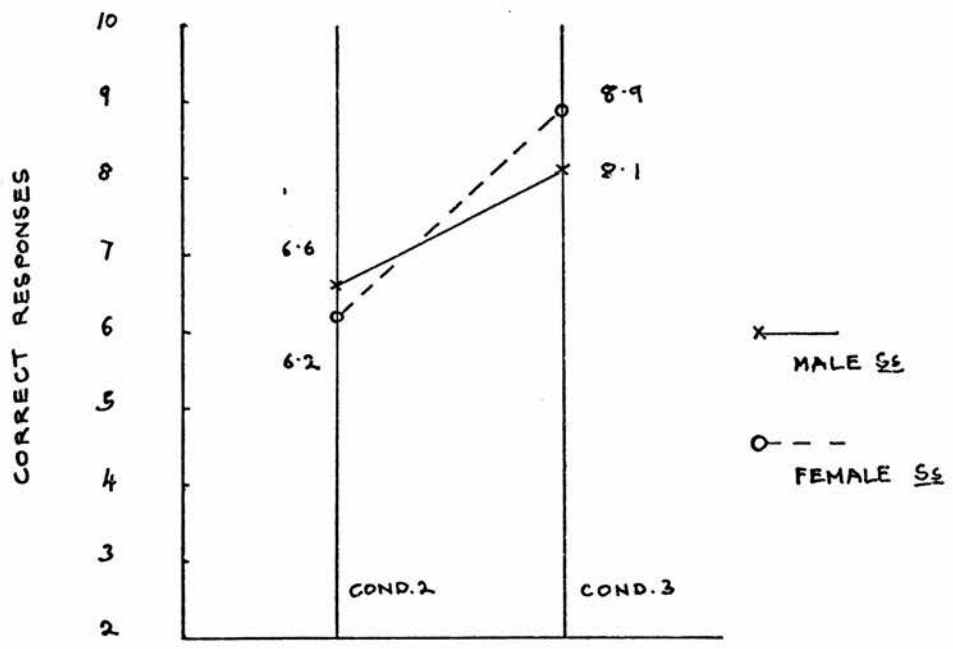
MEAN NUMBER OF CORRECT MOTOR RESPONSES

FIG. 51

MEAN NUMBER OF MISSING MOTOR RESPONSES

FIG. 52

MEAN NUMBER OF MOTOR INTRUSIONS

FIG.53

MEAN NUMBER OF CORRECT VERBAL RESPONSES

FIG.54

MEAN NUMBER OF MISSING VERBAL RESPONSES

FIG.55

MEAN NUMBER OF VERBAL INTRUSIONS

FIG.56

213.
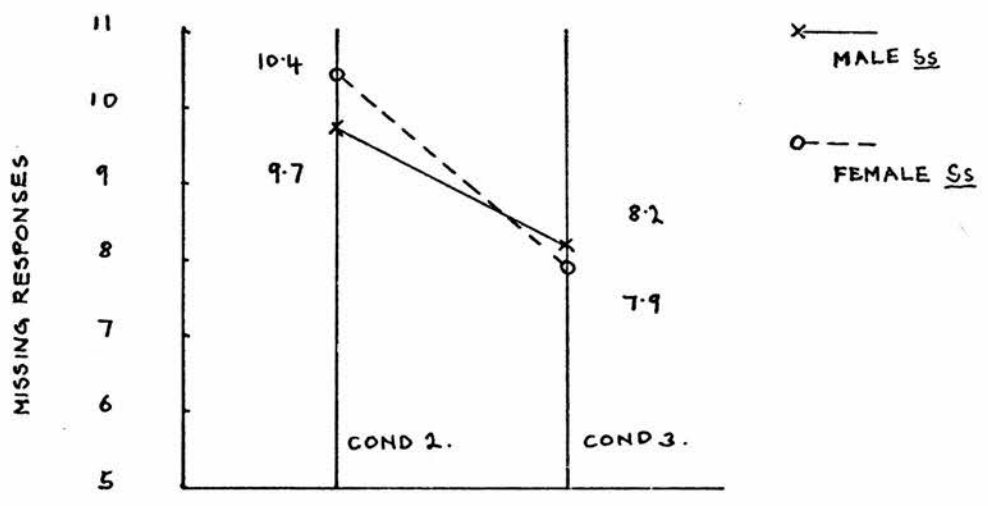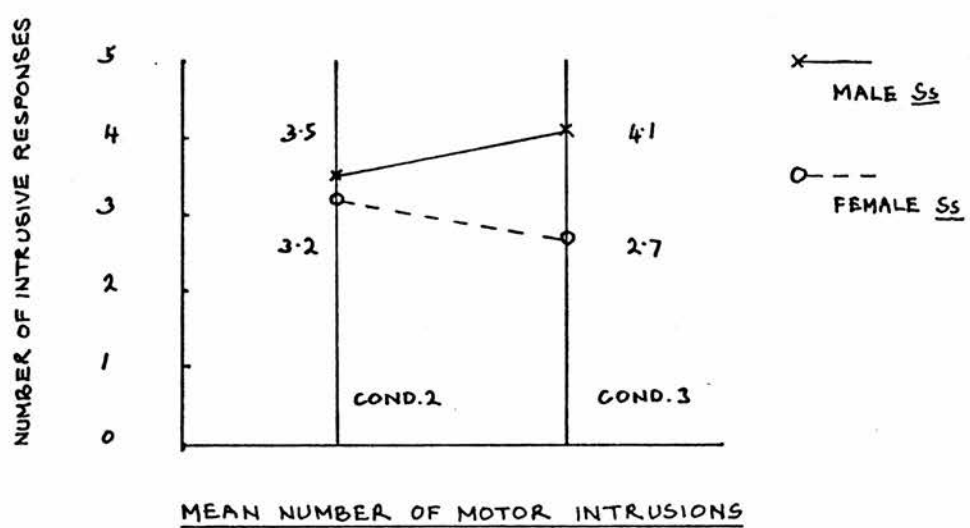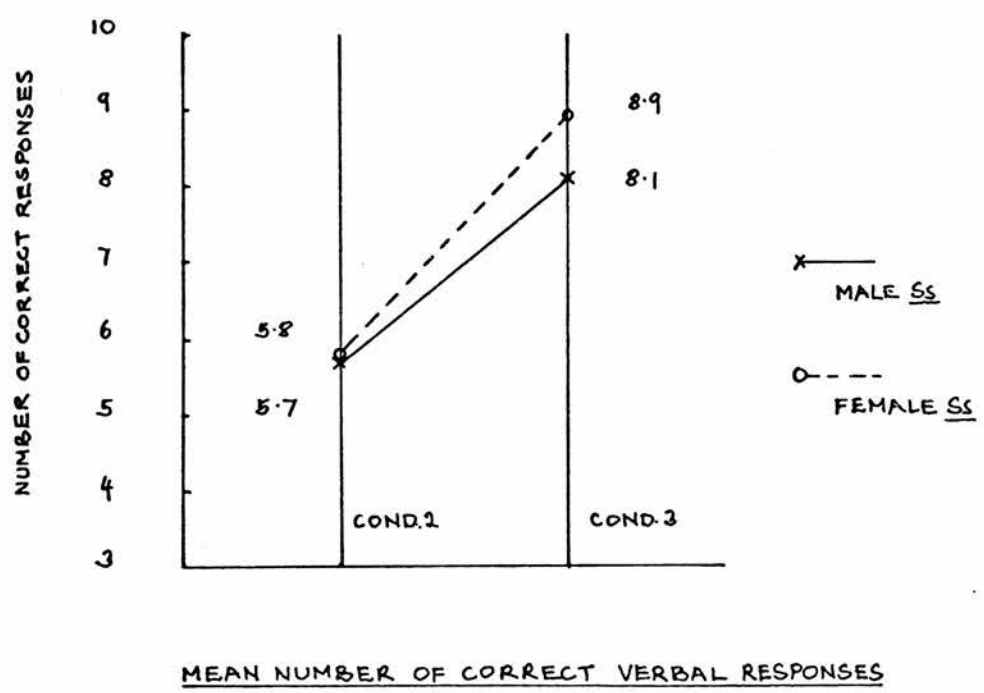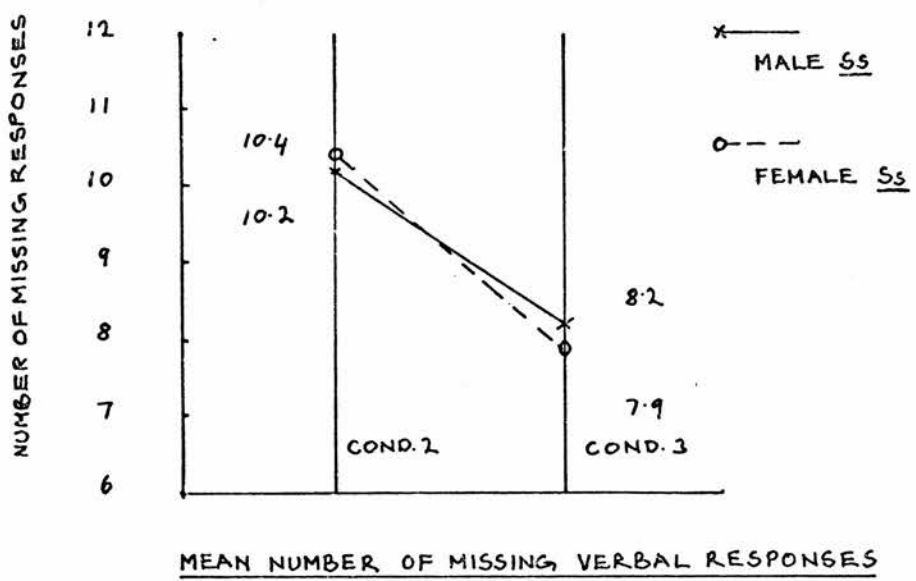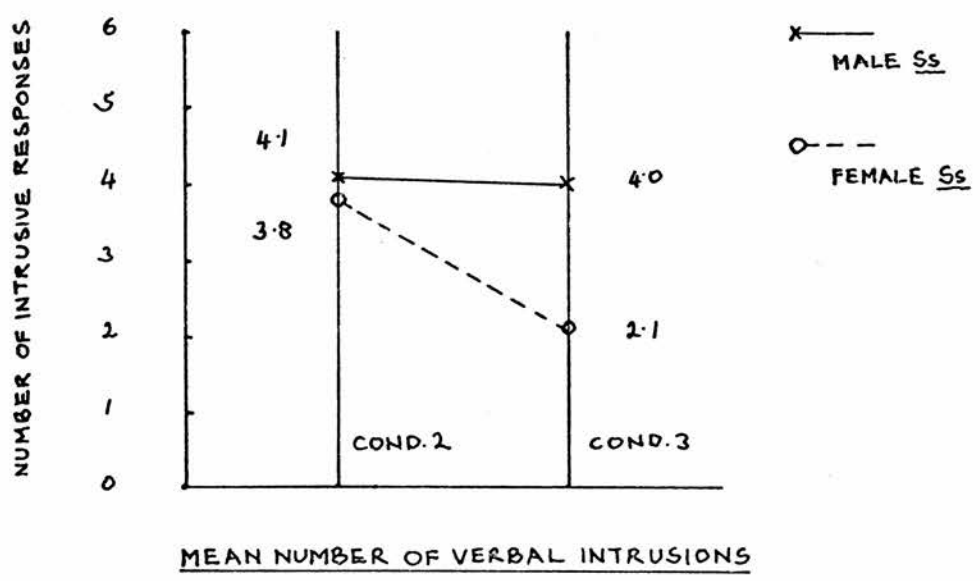
Discussion

The main purpose of Exp. 7 was to test the hypo-
thesis that in the conditions of the experiment there
would be more mistakes of pressing the wrong button than
of saying the wrong word.   This hypothesis is in
accordance with Luria's theory that the verbal system
dominates the motor system in a situation in which they
are at odds with one another, as they were in the
conditions of this experiment.

The results show that when the combined scores of
the two experimental conditions are considered together
there is no evidence that there are more motor than
verbal intrusions.   Luria's hypothesis, then, is not
borne out by this experiment.

Inspection of Figs. 46 and 47 suggests why Luria's
hypothesis is not supported by the data.   In condition
3 (where the motor responses are incompatible with the
stimuli) there is indeed a higher number of motor than
verbal intrusions.   In condition 2, however, the
situation is reversed: there are a higher number of
verbal than motor intrusions.   In this respect, then,
the graphs are identical in form to those of Exp. 5
where the same relative positions of the mean numbers of
verbal and motor intrusions were found (see Fig. 40).
It is this reversal of the relative numbers of verbal
and motor intrusions in the two experimental conditions
that evidently stops the overall means for the two sorts
of errors from being different.   The graphs are not of

the form that would be predicted by the verbal regula-
tion theory, which would expect that the number of motor
intrusions would be greater than the number of verbal
 intrusions in both cases.   They are, though, of the
form predicted by the Capacity theory.   Previous
elaboration of the theory has shown how it predicts
'pseudo-dominance' of the verbal over the motor system
in condition 3, here agreeing with Luria, but 'pseudo-
dominance' of the motor over the verbal system in
condition 2.

A statistical examination of the number of
intrusions shows that for condition 3 - where the
Capacity and the Luria predictions coincide - the
differences indicated by the graph are indeed signifi-
cant.   Unfortunately for the Capacity theory in
condition 2 the number of verbal intrusions, though
greater than the number of motor intrusions, is not
significantly different.   One reason why the predictions
of the Capacity theory in the very important condition 2
have not achieved significance may be because of the
presence of Ss who made only a very few correct
responses.   The Capacity theory predicts the apparent
dominance of the motor over the verbal system in a
situation of high-load where, under pressure, it proves
impossible for the S to sustain the 'set' to reverse his
verbal responses, so they lapse into compatibility with
the stimulus.   Where a S is only making a very few
motor responses the preconditions for this apparent

dominance will not hold.   In order, then, to give the
Capacity theory a real opportunity to show the presence
of the totally non-Luria-like phenomenon of apparent
motor dominance it is necessary to select a group of
high scorers and examine their behaviour in the crucial
condition 2.   When this is done the fact clearly
emerges that there are indeed significantly more verbal
than motor intrusions.   It would have been very satis-
factory if, for this selected subgroup of high scorers,
the corresponding lapse of the motor system into
compatibility in condition 3 could have been demonstrated.
Unfortunately in condition 3 the difference between the
number of motor and verbal intrusions does not achieve
significance as it does for the larger unselected group.
The trend is, though, in the predicted direction.

The procedure of selecting a subgroup of high
scorers is not entirely satisfactory and is open to the
following objection: suppose that Ss differ in their
tendency to ignore one or other of the response channels,
say, exhibiting a bias in favour of making correct motor
responses at the expense of the verbal channel.   If
this were so then the technique of selecting Ss with
high motor scores would simply select Ss with this
response bias.   Given such a bias then this group would
of course show more errors of intrusion in the verbal
than the motor channel.   If this argument is sound then
the dominance of the motor over the verbal channel might
not result from the S-R compatibilities of the various

facets of the task, as the Capacity theory maintains, but could be a mere artefact of selecting Ss with a certain sort of response bias.

To overcome this objection it is necessary to consider the data regarding the 'unbiased groups'. These Ss are not neglecting one task in favour of the other, and in particular are not neglecting the verbal task in condition 2.   In this group, as with the high scorers, the result again emerges that in condition 2 it is the incompatible verbal responses which show more intrusions, whilst in condition 3 the greater number of intrusions is shown by the incompatible motor responses.   Selecting unbiased groups overcomes the objections to selecting high scorers and reinforces the conclusion that S-R compatibility is the important variable determining the number of verbal and motor intrusions.

Now that the main results of Exp. 7 have been related to the hypothesis under test the discussion can be extended to cover the more general trends in the data. These differ in interesting ways from those encountered before and afford an opportunity to fill out the picture that has been drawn of the workings of the Capacity theory.   It also points to ways in which it might be tested.

When the Capacity theory was first introduced the two parameters dx and dy (representing increments of

difficulty in the motor and verbal tasks when
incompatible responses are required) were assumed for
simplicity to be equal.   The real relative sizes of
these parameters is not in fact specified by the theory.
Clearly whole families of predictions could be drawn
from the theory depending on the relative sizes assigned
to these terms.   (The same point applies to the term dz
representing the increment of difficulty due to the need
to produce two sets of incompatible responses.)   The
policy adopted regarding the values of dx and dy was to
let the theory follow the facts and to conclude from the
observed performance of groups of Ss which of the two
values was the larger.   In the case of the group of Ss
used in Exp. 6 it seemed that reversing the motor
response was more difficult than reversing the verbal
response, viz. dx $>$ dy, although there is no reason
a priori why this should have been the case or why all
groups of Ss should behave in the same manner in this
regard.

An examination of the graphs of the number of
correct and missing responses for the group of Ss of
Exp. 7 suggests a reversal of this relationship compared
with the Ss of Exp. 6.   In Exp. 6 there is an overall
tendency for Ss to find condition 2 easier than condition
3, while in Exp. 7 it is the condition in which the
verbal responses have to be reversed that is found more
taxing, i.e. dx $<$ dy.   Both of these forms of behaviour
are perfectly compatible with the Capacity theory but

they do involve the conclusion that there is a difference
in balance between the motor and verbal systems in the
two groups - and this fact needs explaining.

The degree of difficulty in making a reversal in
the verbal labels of a pair of lights might be associated
with the general level of verbal fluency and maturity.
Imagine two groups of children, one of high verbal
fluency, one of low fluency, then they might well be
evenly matched on the motor aspect of the tasks of
Exps. 6 and 7 but differ with regard to the verbal
facets of the task.   This equality with regard to motor
skills but difference in verbal fluency could easily
produce a situation in which the overall levels of
performance on condition 3 were approximately equal but
the less fluent $\underline{Ss}$ would find condition 2 markedly more
difficult than the fluent group and also (unlike the
fluent group) more difficult than condition 3.[*]

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[*] To make this claim more concrete it will be worked
through with hypothetical numerical values to prove
that the Capacity theory really does entail these
conclusions.   Giving the symbols their usual meaning
the high fluency group might have the following
capacity requirements for the different facts of the
task of Exp. 7: $x + y = 40\%$, $dx = 15\%$, $dy = 5\%$,
$dz = 15\%$;   and for the low fluency group, $x + y = 40\%$,
$dx = 15\%$, $dy = 30\%$, $dz = 25\%$.   Notice that the
relationship between dx and dy is reversed in the two
cases and dz is larger for the less fluent group.
This represents the condition that the interference
between the verbal and motor responses becomes greater
the less practised the verbal labelling skills.
(This is in accordance with the known facts about the
facilitating effects of verbal labels depending on
their being overlearned, since otherwise they can
actively interfere with building up and maintaining a
discrimination (Spiker, 1963).   Substituting these
values into the Capacity theory, see Table 29, the
fluent /

Turning from hypothetical cases to the actual $\underline{Ss}$ of Exps. 6 and 7 it is found that they perform approximately the same in condition 3 and that it is in condition 2 that they differ markedly. What is more, they differ in the way predicted for the hypothetical high and low fluency groups. But is there any reason for assuming that one group consists of verbally fluent children and the other of verbally less fluent ones? The answer is positive: the groups may indeed differ in their speech habits in the way required to account for their different performances. The $\underline{Ss}$ were drawn from different schools whose catchment areas had markedly different social characters, but more important is the fact that the tables giving the Peabody Vocabulary Test scores for the $\underline{Ss}$ shows a difference in the mean raw scores of the two groups of some 7 or 8 points (or approximately 12%). The high vocabulary scorers were the $\underline{Ss}$ of Exp. 6, the low vocabulary group the $\underline{Ss}$ of Exp. 7 as required by the above account.

This explanation as it stands is clearly $\underline{ad\ hoc}$ but it may have some value in that it points to a way in which the Capacity theory might be tested. If the verbal and motor aspects of the task of Exp. 7 were examined in isolation it should be possible to detect $\underline{Ss}$

(Footnote contd. from p. 218)

fluent group has a total capacity requirement of only 60% for condition 2 but 70% for condition 3. The less fluent group would have a not too dissimilar requirement of 80% for condition 3, but a full 95% for condition 2.

who have markedly greater difficulty with the motor
reversal compared with the verbal reversal, and **vice
versa**.   If two such groups can be located the Capacity
theory makes predictions about the relative difficulty
of the two conditions of Exp. 7 for the different groups
when the motor and verbal tasks are combined.   In this
way, rather than simply waiting for a group of $\underline{Ss}$ to
define themselves, 'after the fact', as it were, as
having such and such a relation between dx and dy, a
prior commitment can be made as to the direction of the
inequality and its consequences can be tested.[*]

Conclusion

Exp. 6, with its biased recording of the verbal
responses, had suggested that perhaps overall there were
more motor than verbal intrusions when the two systems
were in competition.   This would be in accord with
Luria's theory of the verbal regulation of behaviour.
The more accurate measurements of Exp. 7 permit this
suspicion to be dispelled.   There is no significant
difference, overall, between the number of motor and
verbal intrusions when both the incompatible conditions
of Exp. 7 are considered together.   Rather, the verbal
system tends to dominate the motor system when the motor
responses are incompatible with the stimuli, and the

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[*] This test does, though, rest on the assumption that
equal numbers of errors in the two response channels
represent equal demands for greater capacity and the
validity of the test is thus limited by how near or
how far this is from the truth.

motor system tends to dominate the verbal system when
it is the verbal responses which are incompatible with
the stimuli.   So no overall postulate of verbal
regulation or domination needs to be admitted.
Although there are many anomalies the Capacity theory
rather than the regulatory hypothesis seems to represent
the most revealing way of looking at the data gathered
in the last three experiments.

CHAPTER V

SUMMARY AND SUGGESTIONS FOR FURTHER WORK

The purpose of this chapter will be twofold. First of
all the theoretical and experimental investigations of
the previous chapters will be re-introduced, summarised
and surveyed. Second, a number of possible lines of
further enquiry will be briefly developed.

Summary and Survey

The central problem has concerned the various
claims that have been made regarding the function that
language plays in the self-regulation of behaviour.
That language is connected with the regulation of
behaviour is a truism; people can be instructed how to
perform tasks, how to sequence their actions and how to
select the goals of their behaviour. The many
instances of the regulation of one person's behaviour by
another (as in the case of a parent and child or driving
instructor and pupil) has led to the idea that a person
may act as his _own_ instructor and regulate his own
behaviour by means of his own verbal output. On intro-
spective grounds this idea has a certain plausibility.
Sets of directions for an unfamiliar route are memorised
and repeated at crucial decision points. This is a
very 'intellectualistic' model of behaviour in that it
suggests that each action is preceded by another more
fleeting action of taking thought. The dangers of

infinite regress in this situation are clear and they
have led to the condemnation of whole classes of such
theories by modern analytical philosophers (for example
Ryle (1949) but see Bloor (1970)).   Nevertheless, such
accounts of behaviour have been taken seriously by many
thinkers.   One concrete development of such a theory
has been by the Soviet psychologist A.R. Luria working
within the framework of ideas supplied by his fellow
countryman L.S. Vygotsky.

The main thrust of Vygotsky's work as it applied to
child development lay, on the one hand, in exhibiting
the growth of the classificatory skills which lie at the
root of conceptual thinking, and, on the other, in
tracing the internalisation of language.   It is
internalised language, with all the qualitative changes
that it has undergone in the process, which mediates the
self-regulation of behaviour on Vygotsky's view.
Children acquire language skills from the adults around
them as an integral part of a process of social inter-
action and whilst acquiring a host of other behaviour
patterns.   Regardless of how the process of learning
and socialisation is envisaged, the end result is that
adults in a large measure succeed in regulating a
child's behaviour.   There is also little room for doubt
that normally the verbal output of the adult plays a
significant role.   One of Vygotsky's central claims was
that the verbal aspect of the parent-figure's role is
taken over by the child's own verbal system which becomes

a source of self-instructions.   Vygotsky might be
looked upon as providing a counterpart to the Freudian
theory of the internalisation of the moral sentiments
of parent figures in the 'super-ego'.[*]

Luria has sought to experimentally investigate and
illustrate the fine structure of the process whose
general course was sketched by Vygotsky from the stand-
point of social psychology.[**]   He sees language as

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[*] The complementary character of Vygotsky's and Freud's
views may not be an accident.   Wortis (1950) says
that in the decade after the revolution a number of
Soviet psychologists expressed interest in Freud's
views.   This trend towards 'idealism' was later
condemned, as was Vygotsky's book Thought and
Language.   Early work on the influence of words on
behaviour was viewed in the 1950s as typical of the
heretical attempt to reconcile mechanism and idealism.
Interestingly, Luria was on the editorial board of
the International Journal of Psycho-analysis between
the World Wars.

[**] Work that is explicitly a development of the social
dimension of Vygotsky's thought has been performed by
Bernstein (see for example Bernstein, 1965).   Bern-
stein has traced the social class correlates of
different styles of linguistic relationship between
parent and child.   A detailed articulation of goals
and the means of achieving them, of snags and errors,
of approved and disapproved procedures, is character-
istic of the middle class parent and child.   A far
less linguistically differentiated code of inter-
action is associated with many working class homes.
For example, in this 'restricted code', to use
Bernstein's terminology, children are simply told to
stop a certain line of behaviour, whereas in the
'elaborated code' they are told to stop it for a
specific reason.   The elaborated code thus permits
children to make finer discriminations about their
own behaviour and its impact on other people.   The
enhanced analytical power which such a child will
develop will inevitably be mirrored in more sophisti-
cated possibilities for the choice and regulation of
behaviour.   Lest it should be thought that
Bernstein's work is an ideological tract on behalf of
middle class values and habits it should be pointed
out that Bernstein's own perspective on the matter is
that /

being able to perform its regulatory function in children because, after a certain stage, it is more highly developed than the motor system. It is more 'mobile' and 'flexible' in that it can produce more accurately timed and selected responses. The deficit that Luria - at one stage in his thought - postulated in the motor system is that it suffers from inadequate proprioceptive feedback. The significance of this type of deficit has been well demonstrated in a variety of studies. This claim has been supported by Luria's argument that the introduction of enhanced feedback improves a child's motor skills. For example in a task requiring the pressing of a rubber bulb each time a light flashes a young child's performance is said to be greatly improved if feedback is introduced in the form of a buzzer which sounds when the bulb is pressed. This is the basis of one of Luria's models of the way in which language regulates behaviour; it helps to close a feedback loop and hence takes over the role of the buzzer in the experiment just mentioned.

One of the first theoretical steps was a detailed examination of the way in which Luria's theory depended

(Footnote contd. from p. 224)

that the two codes are determined by, and adapted to, quite different social situations. Under the influence of Durkheim he sees the categories of thought within a culture as determined by the social structure. An extremely interesting set of claims regarding the disadvantages of a highly articulate, individualistic home background is to be found in the recent study by the anthropologist Mary Douglas of the social causes of anti-ritualist attitudes (Douglas, 1970). Douglas's study takes Bernstein's and Durkheim's work as a starting point.

on this model of the feedback loop.   The conclusion was
that Luria could only make the dependence fully coherent
at the expense of being arbitrary.   Rather than leaving
the issue hanging on purely conceptual arguments an
attempt was made to check the experimental results on
which Luria's claim rested.   If the observed result of
introducing enhanced feedback was not as Luria asserted
then the 'model' is simply not there to be used at all.
Exp. 1 was thus an attempt to replicate Luria's buzzer
experiment.[*]

Two groups of children of approximately 4 and 5
years of age respectively were presented with a sequence
of light signals, some yellow, some blue.   On the first
occasion Ss simply had to press a rubber bulb for the
blue but not the yellow signal.   On the second run the
task was the same but half the children in each group
received enhanced feedback in the form of a buzzer which
sounded for every press.   The hypothesis tested was
that the improvement in performance over the two runs
would be greater for the feedback groups.   The result
was that for the older children there was indeed a
significantly greater improvement for the feedback
groups, but this was not so in general for the younger
children.

The implication of this result is that because

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[*] Details of the ages and numbers of Ss used, stimulus
values, order of conditions, etc., will not be given
in the following brief summaries of the experiments.
Only the general outline of the design and the more
prominent results will be mentioned.

there was no improvement due to feedback found in the younger group the model situation is not available for use in the way that Luria requires.   Indeed, the result goes strongly against Luria because it is precisely the older Ss (who should have less motor deficit) who benefit most from the introduction of feedback.   There was in fact a suggestion, though not a statistically significant one, that the younger Ss were impeded by the presence of feedback.   An explanation for the results was proposed in terms of an arousal theory.

The second experiment was designed to check another important precondition of the Luria theory, namely that the verbal system in children is more developed than the motor system.   The task was similar to that of the previous experiment, involving responding to the blue but not the yellow signals that were presented in a predetermined sequence.   There were two conditions, in one the response was a bulb press, in the other it was to utter the word 'go'.   Again two groups of children were used, the younger having a mean age of just over 4 years, and the older a mean a few months short of 6.

The result provides at least a small amount of support for Luria.   If the Ss of both ages are grouped together then there were significantly less verbal than motor responses missed out.   In this respect, then, the verbal system does seem superior to the motor system, although no other measure of performance displayed this

trend.   The results clearly showed, however, that the
verbal system was only scoring about 2 out of 3
responses correctly.   This was completely counter to
the impression derived from quoted statements of Luria's
which were meant to apply to Ss even younger than those
used in this experiment.   The second experiment, then,
did not exhibit the verbal system working at the level
of efficiency that a reader of Luria's might expect;   so
however the process of regulation is supposed to work,
the verbal system did not emerge as being in a position
to impose much improvement on the motor system.

The first two experiments related to certain
important theoretical details of the process of verbal
self-regulation.   Although the experiments were very
limited in scope they permitted inferences regarding
issues which were quite central to Luria's case as he
presented it.   It is possible, though, to discern a
variety of levels in Luria's theoretical ideas and to
find a general formulation of his position which is
independent of the detailed models which were the focus
of the first two experiments.   The first chapter ended
with this general form of the theory constructed by
quoting from Luria's works.   The general form of the
theory implies that all motor activity in children comes
to be verbally mediated after the age of about 5, and
that to prevent the participation of the speech system
will result in the disruption of motor performance.

The second chapter began with an examination of

some Skinnerian experiments on the regulatory role of verbal 'operants'. This work was explicitly related to the Soviet contributions and focused on the general form of the regulatory thesis. Again the initial stage of the argument was a theoretical analysis of certain key experiments, and again the analysis revealed obscurities surrounding the claims made. In particular the terminology used in the statement of experimental results disguised the fact that sometimes verbal responses interfered with motor responses rather than assisting them or regulating them. This suggested that it may be fruitful to develop an alternative to the regulatory hypothesis stressing the interference between the concurrent performance of a verbal task and a motor task. This step was the first stage in the development of a theory of the relationship of the verbal and motor systems which appealed only to the capacity requirements of the two response modalities. In its first phase, however, the alternative approach was formulated in terms of the older concept of 'load'.

The task of the second chapter was to see if various Skinnerian experiments claiming to demonstrate the regulatory function of language could be accounted for in terms quite different from Luria's. For example, it had been claimed that if children are given a tapping task (with no speed of tapping specified) then making Ss repeat the word 'fast' speeded up their tapping, whilst making them repeat the word 'slow' slowed it down. It

had also been claimed that for 5 to 6 year olds overt
verbal responses were more effective than covert or
whispered ones, whilst for 6 to 7 year olds it was the
covert responses which exerted greater control.   The
first step to finding an alternative to the regulatory
hypothesis was to establish that repeating a word,
whether overtly or covertly, imposed a load on the
nervous system which would influence the conduct of a
motor task.   The second step was to see if the
allegedly different regulatory influence of the overt
and covert responses could be shown to be an artefact
due to the different loadings of the two sorts of
response.   The strategy was to see whether the alleged
regulatory influence of the words might be an inverted
formulation of what is really a load phenomenon.

In Exp. 3 a group of nursery children and a group
of infant school children were given four runs on a
tapping task.   The first and last runs were simply to
establish how fast they could tap.   The middle two runs
demanded rapid tapping along with the repetition of the
word 'fast'.   On one occasion the word was repeated
aloud, on the other it was whispered.   The result was
that both the overt and the covert verbal tasks inter-
fered strongly with the rate of tapping.   The experi-
ment did not however reveal any significant differences
in the loadings imposed by overt and covert responses,
although there was a non-significant trend in the
direction that would be required to account for the

alleged difference in regulatory function. This experiment, with the repetition of the word 'fast' strongly interfering with the speed of tapping, provides a demonstration, not merely of the failure of self-instructions to have any influence, but of their having the opposite effect.

Objections to this experiment were then considered in order to formulate the line of attack of Exp. 4. For example, it could be argued that a fast tapping task was very demanding so that of course any concurrent verbal task would take its toll. What is required is a knowledge of the different loadings imposed by self-instructions that were compatible with the motor task compared with self-instructions which were not consonant with it. On the regulatory thesis saying 'fast' may impose a load on a fast tapping response, but not as much as saying 'slow'. It was also clear that the influence of such self-instructions on slow tapping should be investigated. Both of these points were taken up in the next experiment which was a comparison of the influence of commands and 'countermands' on a motor task.

A group of infant school children were given four runs on a tapping task. On two of the runs they had to tap rapidly and on two they had to tap slowly. On one fast run and one slow run they had to repeat the word 'fast' and on another fast and slow run they had to repeat the word 'slow'. Half the children repeated the

word aloud (overt group) and half in a whisper (covert group).   One of the main results of this experiment was to establish what Exp. 3 had failed to make clear: that for infant school children the overt utterance of the word 'fast' in a fast tapping task imposed a signifi-cantly greater load than did the covert utterance of the word.   The same trend was discernible for the counter-mand condition but did not achieve significance.   The experiment also established, however, that for the covert group in the rapid tapping conditions S̲s̲ tapped more rapidly when saying 'fast' than when saying 'slow'. Here the conclusion had to be in favour of the regulatory hypothesis.   The meaning of the spoken self-instruction was having a significant effect on the motor performance.   What was not proven was the way in which the spoken words were influencing the motor task: it was possible that it was doing so by essentially non-Luria processes, say, by influencing motivation.

At this point some victories had been won by the 'load' picture which stressed the independence of the verbal and motor systems in all respects but competition for capacity.   On the other hand a significant piece of evidence in favour of the regulatory hypothesis had also come to light.   The predominant relationship between the verbal and motor outputs was given by the 'load' picture, but a significant second order effect was present in which self-instructions seemed to be regulating behaviour.

The next stage in the investigation was to move
away from the tapping tasks used in the previous experi-
ments to tasks which would provide more insight into the
details of the processes postulated by the regulatory
hypothesis.   The previous chapter had, however, provided
an appropriate setting for the development of some basic
theoretical approaches which could be developed into a
more thoroughgoing alternative to the regulatory theory.
The technique of comparing the effect of commands and
countermands was also utilised in the remaining experi-
ments.   The experimental task was radically modified so
that unlike the simple tapping tasks it involved the
repeated analysis of stimuli and the repeated need to
make decisions in selecting the required responses.
This ensured that the commands and countermands of the
verbal output would have ample opportunity to gain a
purchase on any verbal processes involved in the
organisation of the motor responses.

For the purposes of the next experiments Luria's
theory can be put like this: suppose that S is
presented with a sequence of red and blue signals and
required to press red and blue buttons, one press per
signal.   For a S who is old enough a required motor
response of pressing a red button to a blue light and
vice versa would be mediated by a covert self-instruction.
This would perhaps be of the form 'blue, so red', i.e. a
combined labelling of the stimulus and a compressed
statement of a rule to be followed.   Now imagine the S

also having to produce an overt verbal output which runs counter to the postulated self-instruction: perhaps saying 'blue' when a red press is wanted. Incorrect motor responses would intrude, evoked by the overt verbal response functioning as a self-instruction. But if there is no verbal component involved in the selection of a response then there should be no difference between the amount of interference of commands and countermands. Exps. 5 and 6 were designed to test this picture.

The hypotheses of Exps. 5 and 6 were that (1) motor responses conjoined with compatible overt self-instructions will be performed more accurately than when conjoined with incompatible self-instructions; (2) when the verbal system and the motor system are in competition then Ss will tend to do what they say rather than say what they do, i.e. if they have to say 'red' and press a blue button they will tend to make the mistake of pressing a red button rather than of saying 'blue'. The basic task has already been outlined, but for the purpose of adequate control four different conditions were required of each S. In two of the conditions the button to be pressed corresponded to the colour of the light but in one case the verbal response was compatible with the button press and in the other case it was incompatible. The remaining two conditions were the same except that the button to be pressed was the 'opposite' to the colour of the light. The Ss were

infant school children.   In Exp. 5 the Ss had the
stimulus sequence presented quite slowly (low-load
group) whilst in Exp. 6 different Ss had it presented
more rapidly (high-load group).

The results of the experiments gave a certain
amount of support to the hypotheses and hence to the
regulatory theory.   For example, the compatibility of
the motor and verbal responses was a factor signifi-
cantly affecting the number of motor responses missed
out.   There was also a significant tendency for the
high-load Ss to do what they said rather than say what
they did.   One qualification to the second result was
that the scoring method for the verbal responses was
biased in favour of the hypothesis.

A detailed alternative analysis of the experiments
was then developed in a form which appealed only to the
capacity requirements of the various tasks and
conditions, with no mention of verbal regulation.   A
simple version of the theory was based on the intuitively
plausible idea that to respond to a coloured light signal
with a button press or a verbal label of the same colour
demanded less capacity than responding with a different
colour.   When applied to the task of Exps. 5 and 6 the
simple capacity theory produced radically different
predictions to the regulatory theory.   Consider the
situation where the verbal and the motor responses are
compatible with one another, e.g. when the S says 'blue'
and presses the blue button.   There are two cases, one

in which both responses are compatible with the stimuli
and one in which both responses are incompatible with
the stimuli.   Luria's theory lays exclusive stress on
R-R relationships and so predicts that both of these
conditions will be equally difficult, say, as measured
by the motor responses.   The simple form of the
Capacity theory, though, lays equally exclusive stress
on S-R relationships and so performance should be worse
in one case than the other.   The results strongly
support the Capacity theory.

Other details of the experimental results did not
seem to fit either theory.   The Capacity theory
predicted that the four experimental conditions of Exps.
5 and 6 could be ranked in order of difficulty.   The
predicted order was largely confirmed for the low-load
group, but for the high-load group it was found that
what should have been the most difficult condition was
on a par with the second easiest.   Such anomalies made
it clear that the Capacity theory would have to be
refined.   But any alteration had to preserve the
following useful feature of the Capacity theory: it
could offer in the case of Exps. 5 and 6 an analysis of
what, for Luria, would appear to be the domination of
the verbal over the motor system.   Consider the case in
which the required verbal response but not the motor
response was compatible with the colour of the stimulus
lights.   If the motor responses were to lapse into
compatibility with the stimuli as a result of over-

loading then this would present the appearance of verbal domination of the motor system. This theory of 'pseudo-domination' leads to the opposite prediction to Luria's theory in the case where the verbal, but not the motor responses, are incompatible with the stimuli. This results in the pseudo-domination of the motor over the verbal system. For the low-load Ss the predictions of the Capacity theory are confirmed. For high-load Ss, though, there is no significant appearance of motor domination, although known biases in the scoring of the verbal responses were working against the Capacity theory.

The final steps in the study, in Chap. IV, consisted in (i) a further elaboration of the Capacity theory, and (ii) a repeat of certain aspects of the previous experiments in order to improve the recording of the verbal responses and eliminate the scoring bias. A modified form of the Capacity theory was proposed which made allowance for both S-R and R-R compatibility. This 'two-factor' theory both resolved the anomalous ranking of the various conditions of Exps. 5 and 6 in terms of their difficulty and preserved the important predictions about 'pseudo-domination'. The last experiment, Exp. 7, focused on this important prediction of the Capacity theory concerning the possibility of motor domination of the verbal system. This phenomenon is radically at variance with the regulatory picture of language and its occurrence or non-occurence is thus of the highest importance in judging the merits of the two theories.

The main outcome of the experiment was that, provided the Ss did not bias their responses in favour of either the motor or the verbal channels, then there was indeed evidence of motor domination of the verbal system in the manner predicted by the Capacity theory. The variable which seems to determine the relationship of dominance between the verbal and motor systems is S-R compatibility.

Proposals for Further Work

Suggestions regarding the next steps to be taken after a sequence of experiments has been performed are inseparable from the criticisms that can be levelled at the previous work. Some criticisms of the experiments in this study will therefore be stated as a preliminary to spelling out possible directions for further work.

Many of the criticisms of the seven experiments of this study fall into two categories: these concern (i) areas of interest that were completely ignored in the work but which are related to the experiments that were performed, (ii) ways of analysing and approaching the areas that were chosen for investigation, but which were left unexplored.

In the first category is the criticism that none of the experiments has concerned itself with developmental trends. At the most, two age groups have been taken and compared. This has permitted certain important inferences to be drawn regarding developmental claims made by other workers, but it has not been sufficient to

build up an alternative developmental picture. Also in this category is the criticism that none of the skills and tasks used in the experiments has been examined to see how performance varies with practice.

Perhaps of more importance are criticisms of the second category. For example, none of the experiments has allowed a proper picture to emerge of the individual differences between $\underline{Ss}$. Different $\underline{Ss}$ have shown widely different levels of performance and this fact has received inadequate recognition because of the way that the hypotheses have been formulated and tested.

Another major criticism of Exps. 5 and 6 which falls into the second category concerns a theoretical shortcoming. No adequate distinction has been drawn between the capacity requirements of a task and the capacity allocated to it. Clearly, in general, capacity allocations do not necessarily reflect capacity requirements. This study has not dealt with the way in which $\underline{Ss}$ might have chosen to allocate capacity differentially to one task rather than another. Explicitly instructions were not given to pay equal attention to both tasks, though this was implicit in the training which laid equal stress on both. As Brown (1964) has brought out, in his review of the problems of capacity measurement in a two-task situation, a primary task may be protected by neglect of a secondary task. What is required by the $\underline{S}$ is a clear understanding of which tasks are important and what sort of errors are

permitted.   Lack of instructions on these points does
not necessarily mean that the tasks will be subjectively
assessed as being of equal importance.   For example, in
Broadbent's (1956) experiment on a question and answer
task a subsidiary buzzer stimulus was consistently
perceived as being more important than the primary
stimuli, although no instructions had been given on this
point.   To some extent, then, Exps. 5 and 6 are in
danger of breaking the rules laid down in the discussion
of the Skinnerian work to the effect that experimental
conditions must not be underdetermined.

Some of the difficulty in discerning completely
clear patterns in the results may stem from individual
differences in the importance attached to the verbal and
motor tasks.   On the other hand the theoretical diffi-
culty may not in practice have proved as troublesome as
it might have done.   Inspection of the graphs of Exps.
5, 6 and 7 suggests that, as with some other dual-task
experiments, e.g. Olson (1963), there is a tendency for
scores on both channels to be positively correlated.
(This applies to missing and correct responses.)

A related general difficulty with the sort of task
used in Exps. 5 and 6 is that of the comparability of
the scores on the verbal and motor tasks.   The scores
cannot be easily combined: 7 correct motor responses
and 5 correct verbal responses do not necessarily
reflect the same situation as 7 correct verbal responses
and 5 correct motor responses.   The exception is the

case where the capacity requirements for a correct
response is the same in both modalities.   In the
present experiment this cannot be guaranteed, although
relevant variables like discriminability of stimuli and
probability of occurrence of stimuli and response have
been equated in the two channels.   In the last analysis
some assumptions have to be made about the correspondence
between empirical measures of performance and postulated
processes connecting stimuli and responses, and at one
point in a projected test of the Capacity theory the
assumption of a simple equivalence in the capacity
requirements of responses in the two channels was indeed
made.   The assumption was also implicit in the appeal
to the 'unbiased' groups of Ss where it was argued that
an equal number of missed verbal and motor responses
indicated an equal allocation of capacity.

In principle it is possible to test the capacity
loadings imposed by the tasks of Exps. 5 and 6 on the
motor and verbal channels taken separately.   This could
be done by pairing the separate verbal and motor tasks
with the same subsidiary task and instructing Ss to
perform the primary task as well as possible and to do
the secondary task when they can.   The amount of inter-
ference on the common subsidiary task would indicate the
relative capacity requirements of the two channels.   In
this way an estimate could be made of the extent of the
divergence from equality of demand by the respective
channels.   This technique has the advantage that it

would be still be applicable even if the performance of the motor and verbal aspects of the task were so easy when taken in isolation that Ss showed perfect performance (for a similar case, see Brown, 1962). The limitations of this approach are, unfortunately, severe. Knowledge of the capacity requirements of isolated tasks does not permit confident predictions about how the tasks will interact if they are conjoined. So the basic theoretical problem cannot be solved directly by experiments of this sort. The most that can be hoped for is that as data increases plausible theories of capacity allocation may emerge to solve the problem indirectly.

Other criticisms can be produced which do not fall under the above heads. For example, it is difficult to see any connection between the tasks chosen in the previously described experiments and real-life situations. What, in other words, is the practical importance of the experiments? In reply it is possible to argue that science normally chooses to tackle the simplified problems that it thinks it can solve rather than the more compli- cated and important ones that non-professionals think that it ought to solve (see, for example, Kuhn, 1962). Regardless, though, of the historical precedent for 'triviality' the criticism carries some force.

What are the lines of further research that are indicated by the two main categories of criticism? First, proper developmental data needs to be gathered

regarding children's performance on the tasks used in
this study.   This requirement can perhaps be generalised
to include the need to check carefully the developmental
claims made by Soviet workers in this sphere.   This
point arises because the first two experiments of this
study produced results which diverged from those claimed
by Luria and his co-workers, an experience shared by
Jarvis in his 1963 failure to replicate one of Luria's
results.   In short, there is a need to carefully
retrace the thread of empirical claims made by Soviet
psychologists because a lack of experimental rigour may
well underlie the brief and inadequate accounts that so
often reach us of their work.   Jarvis, for example,
suggests that Luria only used one particular order of
presentation of a set of experimental conditions that in
a well designed experiment would have been presented in
all possible orders.   (For Jarvis's comments see Slobin
(1966) where the complaints of a Soviet psychologist
about experimental standards are also quoted.)   Along
with the need to study practice effects, then, the two
related exercises outlined above provide an extensive
area in which work requires to be done.

The developmental work that has been urged would,
ultimately, lead to a concern with adult performances.
One promising area of application of the experimental
techniques used here, and one major snag, will be
mentioned.   The snag is that the experimental tasks
used in the present study will often be too simple for

a young, healthy adult.   They need to be made more
complicated but without losing their point.[x]   The
The experimental tasks could, also, be used to study the
process of ageing, possibly without in any way modifying
them.   Whatever may be the merits of the Vygotsky-Luria
thesis of the regulatory function of language as applied
to children it may yield interesting results when
applied to the aged.   No doubt various strategies exist
for coping with the problems of ageing but their general
form will involve using one part of the nervous system
to take over or assist in a function normally contri-
buted by another part.   Verbal mediation could possibly
play/more significant role at this stage than earlier.[xx]

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[x]   Pilot studies have suggested that one way in which the
task of Exps. 5, 6 and 7 could be adapted for adult
use would be (i) to remove any prior practice of the
task, and (ii) equip Ss with earphones through which
is presented distracting material, such as a random
repetition of the words 'red' and 'blue'.   Comparison
with non-relevant distracting material might be
interesting here.   Even with distractions, though,
some Ss overcome their initial disorientation after
one or two trials and achieve perfect performance,
though increased task speed may cure this.

[xx]   One of Luria's most striking claims for verbal
regulations concerns a case which is presented as an
example of cortical processes taking over a role
usually played by subcortical ones.   This concerns
cases of Parkinson's disease where the 'injured sub-
cortical apparatus excites repeated tonic responses',
preventing the execution of even simple tapping tasks.
Such patients can, however, tap appropriately in
answer to the question, 'how many wheels has a car?'.
This is held to be an example of the patient
'switching his movements into his speech system and
subordinating them...to the cortical connections'
(Luria, 1959).   Broadbent and Heron (1962) have
established that older Ss are particularly prone to
distraction in tasks involving immediate memory.
This suggests that the task of Exp. 5, with stimuli
presented /

Using the experimental technique with adults, especially the aged, represents, then, another area into which the work might be extended.

Moving now to the question of individual differences a number of issues require examination. First, is performance on the tasks of this study associated in any enduring way with other characteristics? Do they represent but one facet of a relatively stable personal style? For example, how do impulsive children compare with relatively slow and thoughtful ones? That different relationships obtain between the verbal and motor systems in the two cases is suggested by the fact that some success has been experienced in limiting extreme impulsiveness by teaching a child to verbalise before acting (Palkes et al., 1968). That such techniques work does not establish that they mirror or reveal the processes which inhibit impulsiveness in a normal person: but it is rational to investigate the possibility.

Of considerably greater importance is the following problem: there are two ways in which a child can make mistakes in the tasks of the last three experiments. The first way is to forget or muddle the rule that has to be followed in matching the responses to the stimuli.

(Footnote contd. from P. 244)

presented relatively slowly, in a manner which invites inter-stimulus rehearsal, may well provide a suitable context for studying the distracting power of different auxiliary stimuli, hence revealing the type of verbal mediation involved.

The child may then, of course, succeed in following the wrong rule correctly. The second way of making mistakes is to maintain the correct response set but fail to execute it properly. At one point this distinction was appealed to in analysing results. In general, though, there has not been an adequate theoretical or experimental response to the fact that there are almost certainly two qualitatively different types of Ss mixed up together. Probably the best way of ensuring a homogeneous population of Ss in this regard is to increase the amount of pre-training. To ensure that the result of this is not simply perfect performance Ss could be trained at a slightly slower rate of responding than is required in the experimental runs. An alternative technique is to alter the experimental task used in the last three experiments to a self-paced routine. Ss could then make sure that they were following the required rule before moving on to the next stimulus. Differences in the time taken to complete a set number of responses would then be a measure of task difficulty. A study of the importance of individual differences, and perhaps the introduction of a self-paced variant of the last three experiments represents, then, another area for further work.

The theoretical criticism concerning the distinction between capacity requirements and allocation also suggests lines of further work. One way of manipulating the allocation of capacity between the

verbal and motor tasks would be to introduce a pay-off matrix of relative rewards and costs for different sorts of responses and errors. Some success has been achieved by this method in manipulating the distribution of attention (Kahneman, 1970), and in facilitating the performance of a central task at the expense of a peripheral one (Bahrick, Fitts and Rankin, 1952). This issue relates to another problem previously encountered - that no proper account has been given of the different sorts of error reported in the experiment. These could well reflect overall strategies for performing the task in the same way that capacity distribution represents a strategy. Presumably the number of intrusive responses could be cut down by Ss missing out a response unless they were very sure that it was correct, say, by rehearsing the relevant rule or by rechecking the stimulus or its trace. Likewise cutting down missed responses would perhaps inevitably increase the number of intrusions. This suggests that one line of theoretical development would be to try to analyse the experiments of this study in signal-detection terms, where such trade-off phenomena are well known.

So far the suggestions for further research have mostly dealt with general areas that need investigating. Some specific and concrete suggestions will now be examined regarding particular experiments that would be of theoretical interest. Exps. 5, 6 and 7 presented the S with a visual stimulus and required the production

of a motor response and a verbal response.   The key
idea was to set the overt verbal response at odds with
the postulated inner process of verbal self-regulation.
One variant of this would be to make the verbal
component part of the stimulus situation rather than a
response.   If the verbal stimulus were different from
that required by the motor system (as postulated by the
regulatory hypothesis) then it might interfere with the
self-instruction.   As in the previous experiment the
hypothesis that verbal processes are not involved in the
organisation of motor responses would lead to the
prediction that the meaning of the verbal label would
make no difference to the motor performance.   There are
practical difficulties concerned with the synchronous
production of a sequence of light signals and verbal
labels but an experiment along these lines would have a
very similar structure to Exps. 5 and 6.   As with these
experiments it is easy to produce theoretical analyses
from the different points of view of the regulatory and
capacity hypotheses which yield conflicting predictions.
Morton (1969) describes an analogous experiment which
shows both the possible fruitfulness of this approach
and which also suggests that E could deliver the verbal
cues.   In Morton's experiment Ss had to sort a pack of
cards into six categories depending on how many
'nonsense' shapes were on them.   At the same time E
spoke the numbers 1 to 6.   Ss were told to ignore the
distraction, which they soon learned to do, but 'the

interference of the digits could be greatly increased by
speaking the digit name always at the instant that the S
turned up a card'.

Not only would the above experiment provide another
testing ground for the two theories it would also permit
the line of research stemming from Luria's work to link
with another topic which has long interested psycho-
logists: the Stroop effect.   Stroop (1935) established
that when the names of colours are written in inks of a
different colour (e.g. 'red' written in blue ink) it is
difficult to name the colour of the ink because of
interference from the meaning of the colour word.   The
experiment proposed above places the S in a Stroop-like
situation.   The stimulus field contains a colour and a
colour label which is incongruous.   The analogy with
the Stroop situation could be further strengthened by
giving written labels to the response keys rather than
surrounding them with coloured patches.   Luria would
predict that those aspects of the stimulus situation
which are bearers of meaning would predominate over
those that were not, and this is exactly the prediction
that would follow from seeing the experiment as an
example of the Stroop test.

So far the similarity of the Stroop effect to
Luria's claims is no more than a distant analogy, but
the association could be profitably strengthened and
exploited by mapping the experiments of the one field
onto the other.   The proposals for further research

will end with some examples on these lines.   Ellison
and Lambert (1968) have shown that verbal repetition,
which seems to reduce the availability of words, cuts
down the interference of the colour names in the Stroop
test.   If language is indeed a component in the organi-
sation of motor responses then the repetition of words
which might seem crucial for a set of responses should
impair performance.   Another analogous experiment
arises as follows: Pritchatt (1968) has generalised the
Stroop test by using learned associations between
colours and nonsense syllables.   The nonsense syllables
were then presented printed in different colours from
those associated with them.   He found that the inter-
ference between the syllables and the ink colours
depends on the direction of association in the original
paired-associate learning situation.   Should the inter-
ference effect of the incongruous colour name in the
projected Luria-Stroop experiment prove a significant
one then the experiment could be generalised after the
Pritchatt fashion.   Instead of coloured light signals
and colour names learned associations could be used
between, say, illuminated nonsense shapes and nonsense
syllables.   Perhaps here, too, the direction of the
learned association might be a significant variable
determining the dominance relationships between the
verbal and the motor system.

Conclusion

By way of conclusion the main findings of this study will be listed in seven points.

(1) Enhanced auditory feedback does not greatly improve the performance of 4 and 5 year olds on a typical Luria sensory-motor task. The small improvement observed increased rather than decreased with age, thus conflicting with Luria's claim that in young children the observed motor deficits are due to inadequate proprioceptive feedback.

(2) No evidence was found that in 4 and 5 year olds the verbal system was less 'diffuse' and more organised than the motor system and its overall level of performance was lower than would be expected from Luria's quoted remarks.

(3) Verbal self-instructions were found to have a distinct interfering effect on a simple fast tapping task in 4 and 6 year olds. In the older group this interference varied depending on whether the verbal responses were overt or covert, the overt responses imposing a greater load than the covert. This finding permitted an alternative explanation in terms of load for results that others had attributed to the regulatory function of language.

(4) In 6 year olds there was a significant difference in the load imposed by covert utterance of the word

'fast' as compared with the word 'slow' in a fast
tapping task.   This may be an example of language
having a regulatory function or it may be an artefact
due to motivational factors.

(5) In a detailed study of the influence of commands
and countermands in a sensory-motor task many important
features of the results were accounted for in terms of a
theory depending solely on considerations of limited
information processing capacity and making no mention of
verbal regulation of the motor system.

(6) In particular it has been established that where
the motor and verbal systems are in competition there is
no general tendency for the verbal system to dominate
the motor system.[*]   The crucial variable seems to be
S-R compatibility.   Situations were exhibited where the
motor system apparently dominated the verbal system,
which is a phenomenon totally at variance with the
regulatory theory of language.   An explanation for
these facts is offered in terms of the Capacity theory.

(7) On the theoretical level an analysis and articula-
tion of Luria's theory of verbal self-regulation is
offered as well as the development of an alternative
Capacity theory.   It is submitted that the Capacity
theory is more successful than the regulatory theory in
accounting for the experimental findings.

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[*] The operational meaning of the words 'competition' and
'dominate' is given in the detailed statements of the
hypotheses in Exps. 5, 6 and 7.

APPENDIX I

A MODIFIED FORM OF THE PEABODY PICTURE
VOCABULARY TEST

Throughout the seven experiments of this study the
population of Ss has been described in terms of two
parameters: (i) age, (ii) the raw score on a modified
form of the Peabody Picture Vocabulary Test.[*] The full
rules for administering the test are given in the test
manual and were followed in all applications of the
modified test. (The first 100 items of 'List A' were
used.) The Peabody was chosen because it is simple and
speedy to administer, although the raw scores have not
been related to I.Q. measures for British children.
The only difficulty of using it in this country is that
a small number of the words are characteristically
American. To overcome this, each term which was not
likely to be familiar to British children was replaced
by another word provided by E. Although these modifica-
tions were inevitably rather ad hoc they were small in
number and so the test still provided a ready means of
characterising the experimental groups and would have
quickly identified any S who was radically different
from his fellows. The modifications are as follows:
the test item number is given, followed by the deleted

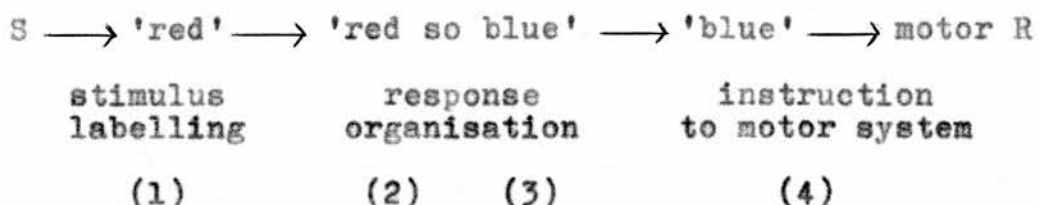item and then the substituted target word. This is either a change in the label of the target picture or a word appropriate to another picture on the same page: 20, (baseball) bat, ladder; 25, weiner, cone; 32, caboose, ambulance; 52, thermos, thermos-flask; 70, stunt, trick.

APPENDIX II

DETAILED DEDUCTION OF THE HYPOTHESIS OF
EXPERIMENTS 5, 6 AND 7 FROM LURIA'S THEORY

The hypothesis is that countermands will interfere more
than commands in the performance of a sensory-motor task.
The text of Chap. III only gives a sketch of how the
hypothesis is deduced from Luria's theory, so a more
elaborate discussion is presented here.   A major
objection to the conclusion drawn in the text concerns
the point of action of the overt verbal utterance on the
covert verbal processes which are held to underlie the
organisation of the response.   Assume that the S is
presented, as in Exps. 5, 6 and 7, with a sequence of
red and blue signals, and is required to press either a
red or blue key, and to say either 'red' or 'blue'.
Now consider the case where the stimulus is a red
signal and the required motor response is to press a
blue key, and the verbal response is to say 'red'.   Let
the diagram below represent the two phases of stimulus
labelling and response organisation where verbal
components are said to be present, and let the numbers
1, 2, 3 and 4 represent the possible stages in the
process where the overt utterance of the countermand
'red' might impinge.   Clearly if it impinges at (1) it
will merely reinforce the labelling of the stimulus and
so will not undermine the production of the motor
response.

S $\longrightarrow$ 'red' $\longrightarrow$ 'red so blue' $\longrightarrow$ 'blue' $\longrightarrow$ motor R

stimulus labelling	response organisation		instruction to motor system
(1)	(2)	(3)	(4)

A similar argument applies if the overt countermand impinges at point (2). The effect of directly interfering with the selection of the motor response will only occur if the overt utterance 'red' slips in, as it were, at the point (3) in place of the word 'blue', or at (4) immediately after the completion of the covert self-instruction. On this analysis it looks as if the chances of the covert countermand 'red' helping the production of the blue key press are as great as the chances of it hindering it. The value of this objection lies in the fact that it suggests a framework for understanding the way in which an adult copes with the task of Exps. 5 and 6. The adult would simply remind himself to call out the name of the stimulus, rather than the name of the response, thus he would 'group' the stimuli and responses in a different way than in the other conditions.

Given the apparent range of different points of action of the overt verbal countermand why was it concluded that the point of action will be (3) and (4) and not (1) and (2)? The reason is that in young children the possibilities of their sustaining strategies for mentally grouping or associating the overt countermand with the stimulus rather than with

the response can be assumed to be less than with an
adult.   If such strategies are adopted they can be
plausibly assumed to be less stable than with an adult.
On this basis the point of action of the countermand can
be assumed to vary randomly, sometimes helping to define
the stimulus, sometimes interfering with the response
organisation.

This now raises the further question of why the
countermand should be assumed to cause more trouble to
the motor performance than the command.   In this case
the command would be the word 'blue', and this too must
be assumed to have a random point of action.   Sometimes
the command will impinge at point (1), that is, on the
analysis of the stimulus.   The result of this is that
it would interfere with the correct identification of
the stimulus, and thus ultimately undermine the response
by feeding an incorrect input to the decision mechanism.
In order to justify the conclusion that commands will
not interfere as much as countermands two assumptions
are necessary.   The first is that the initial colour
naming response will be well established and over-
learned, so it will be highly resistant to interference
by comparison with the more vulnerable 'temporary
connections'.   The second assumption concerns the
detailed structure of the inner self-instruction that
has been represented by the words 'red, so blue'.   On
the basis of Vygotsky's study of inner speech (1962,
esp. pp. 100, 139, 145) the self-instruction will first

be formulated as something like, 'If I see the red I must press the blue,' then it will become, 'If red then blue,' then, 'red, blue,' and finally it will be abbreviated to just, 'blue'. The principle underlying the sequence of abbreviations is a generalisation of Vygotsky's law of the predominance of predication and the omission of subjects in inner speech. That which is apparent and present to the speaker does not require mentioning: 'Inner speech is condensed, abbreviated speech... it is almost entirely predicative because the situation, the subject of thought, is always known to the thinker' (p. 100). The final form of the inner process of self-instruction should be represented by:

$$S \longrightarrow (\text{'red'}) \longrightarrow \text{'....so blue'} \longrightarrow \text{motor R}$$

where the bracket around the word 'red' represents its protected status due to overlearning.

If these two assumptions are correct then, although the point of action of both the overt command and the overt countermand will range randomly across the whole process of stimulus identification and response organisation, it will only be the response side which will be vulnerable, and so the countermand will interfere more with performance than the command. In this way there will be produced a number of intrusive or opposite motor responses which would not have been present if the overt verbal response had not been required, and more intrusions will be associated with the countermands than with the commands.

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Note: On p. 6 there is a quotation from Weiss (1929) taken from Goss (1961). Goss has omitted two words from the original. The original reads, "The speech mechanism that produces the word food thus serves two purposes...," and so does not require the bracketed words added to Goss's version.