UNIVERSITY OF SOUTHAMPTON

AUDITORY-VISUAL COORDINATION DURING EARLY INFANCY

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by

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ABSTRACT

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AUDITORY-VISUAL COORDINATION DURING EARLY INFANCY.

by Marcela Castillo.

A series of experiments was designed with 112 neonates and infants ageing from a few hours to six months, to investigate the mechanism of spatial coordination between auditory and visual information. The experimental subjects were presented with auditory stimuli (either in blocks or at random) and a blank or structured visual field (none, one or two visual targets present).

Infants showed signicant sound contingent oculomotor coordination with the locus of a sound when a visual target was available and the sound was given in blocks of trials. When the auditory and visual systems provided the subject with conflicting information about the locus of the audio stimulus, the conflict was resolved in favour of the information provided by the visual system.

When given random auditory stimulation the infants did not display coordination until they reached 4½ months of age.

The experimental evidence shows that the presentation of an auditory stimulus on its own is not sufficient for the neonate to localize its source. The presence of a visual target supports the auditory system in its response.

The results seem to support the theory of a supramodal mapping of the perceptual senses within which cross-modal information can be detected and integrated.

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Thank you

Marcela Castillo

Footnote:

The World University Service supported this research with a grant to the author.

Portions of the data have been included in papers published by Butterworth and Castillo (1976); Butterworth (1981) and Castillo and Butterworth (1981).

NOTE ADDED BY THE EXAMINERS

The proper use of the binomial test requires that each observation is independent of all the others, otherwise the reliability of effects will be overestimated. On a number of occasions the candidate has used the binomial test where the data are from several subjects, and several observations on each subject entered into the test. However, the candidate has often also provided additional analyses (such as the very conservative independent t-test, as in Table 15) as well as individual analyses which largely confirm that the major findings are robust and that the main conclusions from the experiments are sound. The unacceptable analyses, where grouped data are used, occur in the following places:

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CHAPTER I - INTRODUCTION

I N T R O D U C T I O N

(i) STATEMENT OF THE PROBLEM

The development of the perceptual system from birth to the high level of coordination displayed by adults has given rise to theoretical controversy and interest over the years. We live in a complex world full of different stimuli where the perceptual system must be able to perceive, process and respond to all stimulations. The perceptual system allows us to perceive the world as a coordinated whole where we experience sequences of events and objects which have different characteristics as organized information. We are able to integrate all this varied information without losing the differentiation of the component parts.

Objects can be seen, heard, touched, smelled, etc. We can perceive the stimulation of all our senses together in one integrated situation at any precise moment. At the same time we are able to identify each one of the senses. If we hear a sound, we expect something to be producing it. If we smell an odour, we sniff around for its source. Sounds and smells have to be produced by something that can be seen. The source may be hidden away or be just an image, but it must exist. We even learn to adjust and compromise, and if sound and images are separated through technology (as in the cinema) and placed in different loci in space, we still are able perceptually to match them together.

Are human beings born with this very sophisticated perceptual system that allows us to search for an object when a sound is heard? Is the expectation that an object has to exist in space to produce a sound present in the newborn? Are babies capable of matching a sound to an object, even if the two have a different locus in space? Once this correspondence has been established, do conflicts arise? Is one sense stronger than the other? How does the perceptual system develop from birth to six months? These are some of the questions that originatd this thesis. The experimenter will try to address some of them (even if only tentatively) in the next pages.

(ii) THEORETICAL EXPLANATIONS

Briefly, there are two central explanations of the origin of sensory coordination.

(ii)a) Classical theory.

The classical theory states that development begins from initially separate modalities which are unrelated at birth. This theory, also called empiricist, assumes that the senses are mapped onto separate spatial reference systems making the various perceptual systems function independently. The senses become coordinated during the first month of life through practice and experience of events occuring simultaneously on repeated occasions. The developmental problem then becomes one of synthesis and integration. The perceptual systems become coordinated with each other through experience. This theory was first proposed by Berkeley in 1709, and some contemporary supporters are Hebb (1949); Piaget (1953-1954); Pratt (1954) and Birch and Lefford (1967).

(ii)b) Alternative theory.

The alternative theory, also called nativist, suggests that there is a primitive unity of all senses with a common spatial framework. Development has to start from initially unified sensory modalities and takes the form of a progressive differentiation of the single perceptual system until it reaches a refined discrimination. This idea of a dimension common to all modalities was first proposed by Titchener in 1915. The most important adherents are Haith, J.J. (1969); Gibson, E.J. (1950, 1966, 1969); Aronson and Rosenbloom (1971); Auerbach and Sperling (1974); Lyons-Ruth (1974); Mendelson and Haith (1976) and Field (1980). A variant of this position with the introduction of the supramodal concept was adopted by Bower in 1974.

(iii) BASIC SENSORY FUNCTIONING

Is the newborn baby fully functioning from birth? Can it see? Is it deaf? These are questions that parents ask themselves as soon as their baby is born.

Throughout history there have been different theories of the human perceptual system, and lately there has been an increase in the experimental work in this field.

As early as the 5th century BC, Democritus said that nothing could be in the intellect without being first in the senses, suggesting in this way that the only entrance for all the information is the senses.

With respect to the very famous and widely quoted belief of James (1890) about the world of babies being a blooming buzzing confusion, Mussen et al (1979) speculated that this description could have been a reasonable conclusion for an urban scientist of the last century who must have thought that if the adult world was a noisy and confused place, it must be even more chaotic to the (assumed to be) passive and helpless baby with little power to understand very much about the environment. Nowadays we have enough scientific evidence (some of which will be given here) to believe differently.

Pratt in 1934 considered that the major sensory systems are functional at least in rudimentary terms, from the moment of birth or shortly afterwards.

Carpenter (1974) suggested that more sophisticated information processing capabilitites appear to be operating in the newborn's interaction with its environment than it had been thought possible. He also pointed out that the normal full term neonate is capable from the earliest days of being an acting, perceiving, learning and information organizing individual, capable of processing information received through the sensory system. In the laboratory, infants have shown discrimination, habituation and response to novelty and conditioning. Mussen et al (1979) added that from the moment of birth infants can see, hear, smell, taste and are sensitive to pain, touch and change in position. The newborn's behavioural equipment is also well developed. The neonate has a variety of reflexes, some necessary for survival. For example, newborns will suck a finger or nipple inserted into the mouth and turn in the direction in which the mouth is touched. They also can cry, cough, turn away, vomit, lift the chin and grasp an object.

The newborn is capable of sensing and differentiating certain tastes such as sweet and salty and also can learn to discriminate between various olfatory substances such as the odour of their mother's breast pad and those belonging to another women (Lipsitt 1977).

Thus from the earliest days, the newborn infant plays an active role in selecting the stimulation to which he will attend. This selection depends upon inbuilt functional characteristics of the organism, external stimulus properties and at some point in development, upon memories and associations from experience (which play a role within the first weeks of life). From the moment of birth the infant is a perceptually capable organism with well functioning sensory and motor systems (Carpenter 1974).

(iii)a) Vision in the neonate.

For a long time it was thought that the young infant was lacking in pattern vision or that it could only see vague masses of light and dark. But already in 1930 McGinnis stated that the eyes of the infant are sensitive to light from birth. He noted that infants turn the head towards the light in a slow and inaccurate movement, but nevertheless, make a consistent positive orientation of the head and eyes to the light stimulus.

Pratt in 1934 wrote that although the essential neural mechanisms begin to appear in the third week of pre-natal life, the neuromuscular apparatus involved in vision is still not perfect at birth. However, the infant is able to see light, dark and colours at birth and has remarkably good visual acuity. Pratt suggested that the key to obtain a pursuit movement with the eyes and head depends on the infant being wide awake, the visual stimulus being of proper size and intensity and moving at low speed.

Ling in 1942 observed that visual fixation is absent at the birth of the normal human infant but appears in a rudimentary form a few hours later. In 1962 Fantz et al concluded from their experiments that all parts of the visual mechanism from cornea to cortex function to some degree in the neonate, although further development of the visual structures and functions during the first 6 months causes progressively more acute vision.

Fonarev in 1966 postulated that eye movement is displayed during the first 2 weeks of the newborn baby's life only if a beam of light is reflected from a moving object, crossing a strictly limited receptor zone and shifting along the retina.

The newborn is equipped with flexible information acquisition routines which predispose him to learn about the environment (Mendelson and Haith 1976).

Haith in 1969 and Haith and Goodman in 1982 concluded that the newborn enters the world biologically prepared to explore his environment visually, and does so even in total darkness or in the presence of homogeneous light without any patterned information. The newborn is an active visual explorer. It seems that the components of the visual exploratory system are intact and functioning at birth (Harris and McFarlane 1974; Lewis and Maurer 1980).

In 1965 Haynes et al focused on the very important point of sharpness of the visual image. They suggested that for the first month infants may not make an ocular adjustment to objects of varying distances. It was thought that the infants seem to have fixed focus at about 8 inches (20 cm.) from the eyes. Images of targets nearer or further away are proportionally blurred. Fantz in 1958 found that stimuli shown at 7 to 10 inches (18 to 25 cm.) from a baby's eyes give the sharpes images in the early days of life.

Haith in 1966 added that the organized visual-information acquisition strategies were present at birth but that the structure of the perceptual system was, in a large part, shaped by experience. Mussen et al (1979) reported that infants only 2 hours old would follow a light with their eyes if the speed of the light's movement was not too great. Carpenter wrote in 1974 that infants can see well enough to respond differently to stimuli with differing physical characteristics within the very first days of life.

The ready arousal of various visual reflexes has removed any serious doubts regarding the existence of visual sensivity in the newborn infant (Pratt 1934).

Some experimenters argue that immediately after birth the newborn is capable of maintaining visual fixation, pursuit and visual discriminations (Fantz 1958; Wolf 1965; Hershenson 1964 and Brazelton 1973).

The type of questions asked about early vision have changed over the years. Early research questioned whether and to what extent infants could see. Now we are investigating what kind of visual stimuli infants prefer and what are the information acquisition skills they use (Mendelson and Haith 1976).

(iii)b) Audition in the neonate.

In 1925 Peiper made careful observations of infants' movements before and after birth. Within the first hours after birth definitive changes in the respiratory curves were noted in infants tested with a loud noise. The earliest of these tests was carried out on an infant 25 minutes after birth. Forbes and Forbes (1927) reported that a loud noise could well cause marked movements of the foetus in late pregnancy .

The fact that the newborn infant responds in different ways to strong auditory stimuli has long been known. The tendency for newborns to turn their eyes towards a sound source increases with increased sound intensity up to a particular intensity level. Turning away of the eyes predominates above this level (Hammer and Turkewitz 1975). A very loud noise acts as an irritant even for the infant only a few days old who is capable of making a distinction between tone and noise (Wedenberg 1956; Lavarie and Rudolp 1978).

A baby's reaction to sound can be detected in changes of muscle activities, heart rate, eye movements, head movements, breathing rate, etc. Stimuli which are moderately dissimilar from a newly developed response elicit longer orientation than very dissimilar or very familiar events at any stage of development. All the studies indicate that the human neonate responds to a large number of auditory stimuli of complex tonal variations (Eisenberg et al 1964; Carpenter 1974).

The newborn infant is not only differentially responsive to auditory stimulation, but also posesses the capacity of integrated orientation and defensive behaviour (Kearsley 1973). The capacity to detect a sound as coming from the right, left or straight ahead of the infant seems to be an unlearned ability. When the baby does not respond in exactly the right direction, the cause is more likely to be a deficiency in the motor response system. He may know where the noise comes from but in the early days does not know exactly how to get his head, eyes or hand to function properly. Even so, directionally appropiate eye movements to a sound source have been observed in infants within minutes of delivery (Brazelton 1973).

Eisenberg et al (1964) report babies' reactions to a loud sound 2 hours after birth, and Mussen et al (1979) wrote that the newborn is also capable of locating sounds and discriminating their frequency.

There is plenty of scientific work that experimentally confirms clinical reports of newborn orientation to sound. Babies will turn their head and eyes towards sounds from different sources (music, clicking, clapping, etc.) presented from their side, as well as sound originated from the front. The performance of older infants (3 months) tends surprisingly to be poorer than that of the newborn (Walton 1921; Walker 1921; Pratt et al 1930; Irwin 1932; Froeschels and Beeke 1946; Muir and Field 1979; Field et al 1980; Morrongiello, Clifton and Kulig 1982).

I want to mention in particular the reaction of the newborn human infant to his/her mother's voice. Several authors have described it as striking. The reaction is not one of general agitation, but the baby's body moves towards the origin of the sound. Furthermore, it has been found that infants younger than 3 days of age can not only discriminate their mother's voice from others, but also will work (by selective sucking) to produce her voice in preference to the voice of other females (Thomas and Autgaerden 1966; De Casper and Fifer 1980).

(iv) MAJOR THEORETICAL POSITIONS.

In the next section I will review the position of three researchers who have marked milestones in Developmental Psychology. I will consider Jean Piaget, James J. Gibson and T.G.R. Bower and their points of view with respect to neonatal perception.

(iv)a) Jean Piaget.

Piaget's (1953; 1954) theoretical position on intersensory coordination is that during the first stage of the sensoriomotor period the infant is engaged just in practising the primary schemata. The first actions of the infant are a function of these genetically determined schemata. Such actions are firstly simple and generalized, so that they assimilate all appropiate objects. These schemata are initially independent.

Audition, smell, touch, vision, etc. each have their own separated and unrelated spaces. The young infant may use more than one schema simultaneously, but merely in a parallel isolated fashion. The infant is not trying to deduce two different perceptual characteristics from the same object at this stage. Soon two schemata will become coordinated in an action during the second stage of the sensoriomotor period.

From the second month of life the child tries to look at the object he hears, thus revealing the relationship he is establishing between certain sounds and certain visual experiences. The child expects to see something and this expectation gradually introduces a tendency to consider the visual object as existing before perception, when the infant listens to a sound. In the case of sight and hearing, there exists no objective identity of the visual image with the auditory image at birth , but simply a subjective identity. The child tries to see what he hears because each schema of assimilation seeks to encircle the whole universe. The discovery of the visual picture announced by the sound is only the extension of the act of trying to see. The localization of the sound in space combined with the localization of the visual picture gives objectivity to the object simultaneously heard and seen.

Piaget proposed that cognitive development occurs when the infant is made aware of a conflict or contradiction between two rules, concepts or modes applied to the same situation. There is a constant interplay of assimilatory and accomodative activities originated by the biological need to function. Piaget felt certain that coordination is established only when the infant is able to have expectations about the perceptual qualities of the objects across different modalities. The gradual appearance of head and eye orientations to a sound source in the peripheral visual field has been interpreted by Piaget to mean that auditory and visual space become coordinated during the first four months of development.

(iv)b) James J. Gibson.

James J. Gibson (1966; 1969) has argued that perception can best be understood within a framework in which the traditionally separated senses are considered to form part of a single perceptual system acting to extract the invariant, intermodal information that defines the physical world. His theory of perceptual development has as its fundamental mechanism the increase in differentiation and abstraction of invariant relations in multimodally presented events. Perception does not develop by supplementing the stimulation or by associating responses with it, but rather by the differentiation of stimulation already rich in information. What is learned depends on the detection of the distinctive features of the invariants in stimulation (the higher order relationship that remains constant as other stimulus variables change). Information is invariant over the auditory and visual modalitites when the same relationship characterizes stimulation both to the eye and to the ear. James J. Gibson states that perception of bimodally specified events depends on the detection of such invariants.

The mechanism of perceptual learning is not association but filtration and abstraction. The process is an active one involving exploration and search. The search is directed by the task and by intrinsic cognitive motives, unifying the amount of information to be processed. Perception is thus active, adaptive and self regulated.

Gibson argues that perceptual discrimination becomes decreasingly variable as a function of age. He suggests that underlying the increasing precision in perception is the learning to detect or respond to new variables in the stimulation or an improvement in attention to the critical variables in the stimulation. Applied to intermodal functioning, this position suggests an increasing ability to attend to the stimulation from a single sense modality, in the presence of input from several modalitites. It is important to note that the increasing diferentiation referred to here is not between organism and environment, but rather differentiation among the same modalitites, perhaps developing out of a unity of the senses in early childhood.

According to this view infants become progressively more skilled at detecting invariants that specify significant properties or events in the environment. Even the newborn infant might perceive bimodally specified events if sensitive to the appropiate stimulus invariant.

(iv)c) T.G.R. Bower.

Following Gibson's suggestion that the sensory elements of the infant perceptual world could be considered to form part of a single perceptual system, Bower (1972; 1974(a) and 1974(b)) argued that there may be a primitive unity of the senses at birth. He proposed that perception is supramodal, integrated at birth as an undifferentiated whole and that progressive differentiation and articulation of the sensory modalitites develops through practice. The intermodal unity is greater the more primitive or younger an organism is. The perceptual occurences' characteristics (audio, visual, tactual, etc.) are perceived as an undifferentiated unit in the neonate. This unit, Bower argues, at the same time incorporates modality differentiation.

Bower introduces the concept of a primitive unit with or without modality differentiation. His point is that if the neonate is able to discriminate betweeen the visual and the auditory stimulus and at the same time display spatial coordination between the senses, the primitive unit must have modality differentiation. Otherwise the infant would display spatial coordination but would not be able to distinguish between the different sources of information. That is, if there is no unity of the senses (each one defining its own space), the organism should not be aware of any discordance. If there is no common supramodal spatial framework, there is no possibility that the organism should even notice the discordance. A sound would be heard in its place and a corresponding light seen in its place. If, on the other hand, there is such a complete and perfect unity that sensory inputs are not differentiated by modality, then the only possible outcome of discordance is compromise, the object being perceived midway between the auditory and the visual location. An organism with either of those structures, perfect unity or no unity at all, could never adjust to discordance.

Bower considers the intermediate case of unity with modal differentiation. If the system knows that its different perceptual modalitites perceive the same object, it can resolve the conflicting information by recalibrating one system against the other and hence preserve the unity. In this way the information about the world around us is essentially concordant, even if supplied to different senses. As the organism grows older the degree of sensory unity declines. Adult human beings show dominance of one system with no awareness of any conflict, but babies show distress and greater arousal in the same situation, indicating some modal differentiation. This differentiation increases adaptation by increasing the range of possible different responses.

With regards to the development of this primitive unit, Bower leaves us with the open question of whether the five senses and their neural apparatus evolved independently of each other, or whether a primitive perceptual system (nose, eye, ear. etc.) developed as progressive specializations that still supply the same information to the single perceptual system.

In summary, according to Bower there is a primitive unity of the senses with visual variables specifying auditory and also tactile consequences in human beings. Furthermore, this primitive unity is built into the structure of the human nervous system. The unit is unlikely to have been learned as expectations are shown in children only 2 or 3 days old. This initial primitive unit must develop, leaving a differentiated sensory system in place of a unitary perceptual world.

(v) RELEVANT EMPIRICAL EVIDENCE ON INTERSENSORY COOORDINATION.

There have been quite a few studies on auditory-visual coordination in human infants. Some have been designed to test Bower's hypothesis of the primitive unity of the senses. Unfortunately, the results are still subject to controversy. This may be due to the different methodologies used, measurements taken and subjects selected (Wertheimer 1961; Aronson and Rosenbloom 1971; Butterworth and Castillo 1976; McGurk and Lewis 1974; Lyons-Ruth 1974, among others).

If the common space hypothesis (where both auditory and visual dimensions are represented on a single underlying directional area) is correct, the comparison between auditory and visual information should be able to be made directly. (For detailed reviews see Butterworth 1981; Mendelson 1979; Spelke 1979).

Siqueland and Lipsitt (1966) established a head turning response to one side when a buzzer was sounded and a head turning response to the other side when a bell was rung, with one day old infants. They found the infants able to discriminate between the two qualities of the sound, producing a differentiated response.

Thomas and Autgaerden (1966) asked a mother to call her baby very frequently by its name. By the third day the baby was turning his head towards the mother in response to her call. The baby gave no reaction if somebody else called, or if the mother called a different name. The baby responded to the calling of his own name because the sound renews a sensation already experienced, thus suggesting a remembering process associated with the particular registering of his name. The authors suggest that the baby's response is the result of the deep association which has been established between the impression of the internal life over that related to the environment. The variables that are necessary and have to remain constant in order to obtain the same effective association are the mother's timbre of voice, the intonation, the baby's name and the mother's visual characteristics.

Wolff in 1966 made some studies of babies within two hours of delivery. He found that of 12 infants, 8 visually pursued the source of a sound. Of these 8 infants, 6 turned their head to the source of a sound. He suggests that pursuit movements may be said to have as their goal the prolongation of contact with the stimulus object, or the quest to see what was heard. Even if pursuit is only a primitive form of adaptation that requires no participation by the cortex, visual and auditory pursuit have a direct structural-functional relation with the more differentiated sensoriomotor adaptations.

In 1971, Aronson and Rosenbloom artificially dissociated the human voice from the human face. They presented a voice (coming from a different locus in space than the face), to 8 infants. They observed an increase in the subjects' (30 days old infants) tongue protrusions. They argued that tongue movements could be used as an index to show that the infants were upset and agitated. Following this, they suggested that the infants found in their experimental situation a disturbing violation of their expectations of the perceptual world, in which speaker and voice should share the same spatial position. The experimental subjects's ability to perceive this discrepancy indicates that infant perception occurs within a space that is common to visual and auditory modes, Aronson and Rosenbloom concluded.

McGurk and Lewis in 1974 and Condry et al in 1977 failed to replicate Aronson's and Rosenbloom's experiment. They, as well as Lyons-Ruth (1974), have found the experiment to be methodologically and procedurally weak. The criticisms are several. First, they point out that tongue protrusion have never been validated as an index of infant distress; second, Aronson and Rosenbloom discarded the subjects who showed distress at the beginning of the experiment; thirdly, they failed to counterbalance the sequence of presentations. Furthermore, the agitated behaviour to the dislocation may have resulted not from a violation of expectation, but from response or processing difficulty generated by the increased spatial complexity of the stimulus and the competition between 2 sets of opposite orienting responses (Bower 1974; Lawson and Turkewitz 1980; Broerse et al 1983).

In 1972 Aronson and Dunkeld found that there was an intermediate phase of no response as infants grew older, followed by a clear double orientation including differentiation of the two modal locations. Adults were only transiently aware of auditory-visual discordance; they rapidly suppress the auditory information rather than recalibrate it (Witkin 1949).

Turkewitz et al (1970) found that the majority of the infants tested made initial eye movements in the direction of a brief white noise stimulus. They proposed that babies possess an inborn tendency to orient towards sound.

Bower et al (1970) reported that babies as young as 7 days old would reach for a virtual object and finding no object (the real one being behind a screen), would begin to cry. They concluded that the infants appeared to expect a seen object to be touchable in its seen location, and a seen and heard event to emanate from the same point in space.

It is not clear why a newborn's perceptual expectations should be so defined and so rigid. It would be of considerable genetic cost and doubtful adaptive significance for an infant to be born with a set of well designed beliefs about the perceptual information he will receive. Nature might, with more economy, give him a set of flexible stategies for discovering the multimodal properties of objects and events. Thus infants might innately tend to explore objects and events in several modalities, whenever they can pick up enough information to guide their exploration (Bower 1971; Spelke 1976).

Simpson (1973) carried out some experimental work with adults and concluded that when they need to locate two stimuli, localization latency was shorter when both stimuli were visual and longer when one or both were auditory. Making the stimulus modality predictable did not alter this relationship. An increase in latency also occurred as a result of presenting the stimuli simultaneously. Extensive practice served to decrease latencies, but did not eliminate the increase in time required to process auditory stimuli. The results support the notion that subjects generally use a visual reference system in spatial localization and suggest some temporal limits for auditory localization.

Harris and McFarlane (1974) concluded from their experiments that infants at birth or shortly thereafter had a differentiated field of vision. This differentiation consists in a central and a peripheral area. The neonate can detect and orient towards a stimulus 25° from the midline. However, a central stimulus takes priority over any other in that it inhibits orientation to the periphery. Only when the peripheral stimulus is approximately 15° or less from the midline does the neonate turn towards it. The authors assert that the components of the visual exploratory system are intact and functioning at birth. It is not accurate, they say, to describe the neonate as captured by the stimuli; rather the neonate himself excercises internal control over his explorations of the stimulus array.

Jones and Kabanoff (1975) suggested that the role of the eye movements (at least in adults) is to stabilize auditory position memory. The control of the eye movements leads to accurate auditory localization.

Mendelson and Haith (1976) carried out experiments with infants and observed that the experimental subjects made fixation initially towards lateral sounds. They concluded that auditory information can direct visual activity in the newborn over an extended period of time. They presented this as evidence that the organization of early auditory-visual coordination may be more complex.

Rieser et al (1976) produced a spatially appropiate avoidance response in neonates (from 16 to 130 hours of age), when they were presented with amonium hydroxide. They concluded that neonates are innately sensitive to the radial location of odour.

Lyons-Ruth (1974; 1977) researched with infants from 12 to 22 weeks. The arousal levels of the infants were compared during the presentation of spatially coincident and spatially displaced auditory and visual stimuli. The index of the subjects' discomfort was an increase in the arousal level. Greater arousal was shown by the subjects during the spatially dislocated presentation and most often by those infants who also exhibited accurate auditory orientation behaviour. Her interpretation of the results supports the view that infants perceive auditory and visual inputs within a common space and expect the sound to move in space as an attribute of the visual object. This coordination also occurs in the young infant but at a much lower speed than in a 4 or 5 month old baby. Lyons-Ruth suggests that the infant appears to interpret the dislocation episode as a violation of the following rule: sounds which occur in reliable temporal synchrony with the movement of a visual object are features of that object and should move in space with that object. As the infants perceive the sound as an attribute of the object, they anticipate that the same object will occur again in the spatial duration of a sound.

Field (1977) presented infants (3,5 and 7 month old) with objects and images of objects. The infants' emotional reactions and reaching behaviour in the presence of the images were very similar to the responses to the solid objects. The results do not support the report of previous studies (Bower et al, 1970) who used a similar tactually-visual conflict situation and where young infants became emotionally distressed. Field concluded that the initiation of reaching attempts of young infants is predominantly visually controlled, and any tactually-kinesthetic feedback from prehension seems to produce very little modification of young infants' reaching behaviour.

Spelke in 1976 found that 4 month old infants who were exposed to 2 different films simultaneously but to only one sound track, looked primarily at the film for which the appropiate sound was being played. She concluded that infants are able to perceive relations between sight and sounds in the absence of spatial cues, and that they respond to a perceived intermodal variance with increased attention to the event reaching them over two modalities. They are able to coordinate visual stimuli and sounds on the basis of this intermodal structure. Infants respond to the invariance between visual and auditory information by focusing on those visible events which they can also hear. This attention pattern may be of considerable adaptive significance. An infant who consistently seeks information across modalities, will increasingly come to discover multimodal properties of objects and events.

Spelke in 1979 added that 4 month old infants would know something about how some objects look when they hear such objects if they have intermodal knowledge. She suggests that infants can acquire knowledge rapidly (in minutes) when they have the opportunity to watch an object in a film moving in temporal synchrony with its sound. They use knowledge to guide auditory-visual exploration. They can look directly for familiar objects to which they listen. Infants thus engage in a cycle of exploring and learning about bimodally specified events. The adults' knowledge of visible and audible objects may have begun with this cycle of activity. Cohen in 1979 commented on Spelke's experiments and pointed out that as the infants looked significantly more at the film associated with the sound, this demonstrated their ability to coordinate auditory and visual information.

In 1979 Spelke and Owsly reported their experiments in which 3 to 8 month old infants looked at both parents, and after briefly hearing the tape-recorded voice of one of the parents looked first at the one whose voice they had just heard. Only intermodal knowledge of the parent could guide their visual reaching.

Alegria and Noirot (1978) carried out a study with 48 neonates (1 to 6 days old) where the subjects were presented with the sound of a human voice coming from various directions. The results showed that head movements directed towards the sound sources, eye opening, asymetrical mouthing and crying were more frequent in the experimental group who responded to the voice. The movements might originate in the babies expectations of more or less specific visual input. The data on eye behaviour, head movements and crying, are consistent with such interpretations. In agreement with previous findings, the authors come to the conclusion that the neonate is apparently able to localize sound in space, showing that eye movements are determined by the spatial location of sound and that babies expect a more or less specific visual input at the source of the sound.

Muir and Field (1979) and Field et al (1980) reported that 2½ month old infants consistently turn their heads towards continous speech or rattle sounds presented to the left or right of their midline. Field et al (1980) suggested, as a result of their longitudinal study, that infants can turn their heads reliably towards a lateralized sound during the first 4 months after birth.

Dodd (1979) found that 10 and 16 weeks old infants are aware when sound and lip movements do not match, even though they do not understand what is being said. Several infants showed distress as well as inattention during the out-of-synchrony presentation. Lip-reading information can be processed at an early age, and vision may play an important role in the acquisition of speech perception and production abilities. Awareness of the congruence between lip movement and speech sound is either innate or develops soon after birth.

Crassini and Broerse (1980) carried out a study with infants 4 to 6 days old. They found that the subjects showed significantly more ipsilateral eye movements in the direction of the sound. They concluded that the ability of neonates to integrate auditory and visual information into a single perception was present at this very early age.

Broerse et al (1983) carried out some experiments with 3 month old infants and found that the subjects were more distressed during unimodal presentations (e.g. seeing but not hearing their mothers, and hearing but not seeing their mothers), than during bimodal presentations.

Mendelson and Ferland (1982) tell us that it is well established that audition and vision do not function independently even at birth. Thus, spatial correspondence between sights and sounds influences both visual scanning and habituation of the oculographic reflex. The two perceptual systems are unequivocally related by 4 months of age: spatial and/or temporal correspondence between sights and sounds facilitates visual exploration and learning of auditory-visual associations.

Lawson and Turkewitz (1980) studied 6 month old infants. They found that those infants who had become familiar with an object that moved in synchrony with a periodic sound subsequently looked more at the familiar object than at an umfamiliar one in the presence of the familiar sound, but did not do so in the presence of an unfamiliar sound. This result indicates that 6 month old infants associate or appropiately match an object and a sound that in their previous experience have been spatially congruent and have exhibited a synchronous temporal pattern. The result also suggests that the spatial congruity of events may be necessary for the establishment of the association of auditory and visual events as properties of a common object.

Lewkowicz and Turkewitz (1981) worked with 3 to 4 month old infants. They found that these infants were not only differentially responsive to auditory stimuli of different intensities, but such differential responsiveness was markedly affected by prior exposure to stimulation in the visual modality. They also found that the visual preference of the human infants could be modified by an immediately preceding exposure to sound. Lewkowicz and Turkewitz, as well as Schneirla (1972) suggest that for the young infant the salient characteristics of stimulation are variations along the quantitive dimensions, whereas variations along qualitative dimensions are essentially ignored. They proposed that the infant responds not to the differences in the modality of stimulation, but to the amount of stimulation.

Walker (1982) in his studies with 5 to 7 month old infants found that the subjects consistently increased their visual exploration of facial expression when presented with an associated sound, as compared with the same facial expression without sound. While the infants could detect the discrepancy in an asynchronous pairing of a filmed facial expression and its characteristic sound track, they detected other information that specified a single, affective expression as well. Seven month old looked preferentially at the sound specified by the film, even when the accompanying vocal expression was out of synchrony. Infants are able to detect information (auditory-visual relationships) that is invariant across optic and acoustics displays of a single bimodally-presented affective expression, and perceive them as a unitary meaningful event.

In 1961 Wertheimer carried out a single case study with a newborn baby (3 minutes old) in which he found a rough coordination between auditory and visual-motor space, at least at a reflexive level. Eye movements were obtained in 22 out of 45 trials, 19 of which were in the ipsilateral direction of a click, as was the first response. He concluded that a newborn baby would reliably turn his eyes in the direction of a click made randomly at either ear.

Unfortunately, he had not made clear what kind of auditory stimuli he used (with respect to their intensity, length, frequency, etc.), neither did he specify if the observers were in the baby's visual field.

In 1977, McGurk et al designed experiments with neonates. One of the experiments included four experimental conditions: 1) a moving visual target in silence; 2) a moving visual target synchronic with a moving sound (90 db); 3) a moving visual target simultaneously with a stationary sound; and 4) a moving sound (non-visible). The results showed that when presented with a moving visual target, the experimental subjects displayed an increase in the ipsilateral eye movements. The addition of a synchronously moving sound did not increase the tracking movements. The presence of a stationary sound did not interfere with the tracking of the moving visual target either. Finally, the moving non-visible sound did not elicit visual tracking. McGurk et al reported a very high level of non-responding (more than 80% of the trials). No statistically significant results were found for those subjects who made eye movements in response to auditory stimulation. The conclusion of the study is a confirmation that the neonate is capable of tracking a moving visual target, but that this capacity is independent of auditory stimulation. Wertheimer results were not replicated, and McGurk et al concluded that during the neonatal period, auditory and visual modalities function are relatively independent perceptual systems.

In 1976 Butterworth and Castillo tried to replicate Wertheimer's (1961) observation. Two experiments were performed in which a sound (85 db) was presented to the infant while a continous video-recording of the baby's eye movements was made. In experiment I, 20 newborn infants took part (1 to 4 days old). The infants were seated on the mothers' laps facing a white screen which filled the visual field. All the neonates received 40 random trials of 20 clicks and 20 tones. In the trials in which a response was obtained, 48% of eye movements were ipsilateral and 52% contralateral with the sound. The experimenters postulated that if the infants had a tendency to direct their eye movements on the basis of previous experience, the results might have been a reflection of the way in which the auditory stimuli were presented, i.e. spatially random. In experiment II, 8 subjects took part (1 to 4 days old). Infants received 4 blocks of 10 trials each, (left, right, left, right and right, left, right, left), with counterbalanced clicks and tones. Overall, infants responded in 55% of all possible trials. Responses of trials were 41% to the ipsilateral side and 59% to the contralateral. That is, statistically significantly more responses were in the direction away from the locus of stimulation.

A possible explanation for looking away from the sound source could be found in Turkewitz's et al (1966) report that babies would systematically move their eyes in the direction opposite to the source of the sound when the latter reaches a certain intensity (up to 90 db). Unfortunately, Butterworth and Castillo did not come across this paper before carrying out their experiments.

Overall spatially coordinated behaviour took the form of looking away. The researchers performed a more detailed analysis of the sequence of 4 blocks of trials received by each experimental subject and found definite evidence of spatial coordination. During the first block of trials infants looked away from the auditory stimulus, which suggests that initially the infants may have found the stimulus aversive. During the second set of 10 trials only the infants that had suffered a change in the location of the stimulus (not its quality) showed coordinated looking. During the 3rd set of 10 trials, the performance of all groups was at chance level. After the third and last change a variation solely in the location of the stimulus was not enough to elicit coordinated looking, unless it was accompanied by a concurrent change in the quality of the sound .

The authors pointed out that coordinated looking was clearly a function of the quality of previous experience rather than of its spatial location, since it could only be elicited by the contrast between stimuli and no longer by a change of spatial location. The fact that coordination was not immediately evident after the first response did not support the theory which required the infant to map auditory and visual information into a pre-existing spatial framework without any experimental involvement. On the other hand, the results could imply that an audition based spatial model could be automatically accessible to the visual system, and could support the argument that vision and audition mapped into the same space.

Butterworth and Castillo (1976) suggested that the neonate was capable of spatially coordinated behaviour without the prolonged period of learning assumed by traditional theories. They proposed that the infants might first have constructed a spatial model to reflect the spatial properties of events in the environment. The infant had no stable basis for the construction of the model when the input was random, but when the input was structured the infant coordinated visual behaviour to the spatial properties of the sound. The coordination observed consisted in the main of eye movements contralateral to the locus of auditory stimulation. It is thought not to be very likely that the eye movements functioned to seek out a visual stimulus at an auditory locus; more that they may have helped to stabilize auditory memory for position. Since coordination was obtained in the absence of any prolonged period of learning, the innate coordination hypothesis would seem a more attractive explanation to the authors than the traditional theories.

Eye movements appear to be regulated by a 2-stage model for events in the environment. Initially, coordinated looking was elicited primarily by the change in the location of the sound, that is, by the spatial properties of those events. The second stage of the model concerns the qualitative aspects (e.g. tone or click) of the events at particular spatial locations. Even so a differentiation was made between the infants' ability to construct a model of spatial events in the environment and the possession of a spatial framework in relation to which events are coded.

(vi) PURPOSE OF THE THESIS.

The researcher's objective in this thesis, following the earlier work done with Dr. Butterworth and in the light of the evidence from all the experimental work reported above, is to find out more about the relationship between two sensory modalities (visual and auditory senses) and to explore whether human infants perceive within a common auditory space.

The experimenter was also interested in observing the interrelation between particular configurations of the visual field and organization of auditory stimuli, and how this facilitates or obstructs the reactions of normal human infants during their first 6 months of life.

A series of experiments was designed to test some of the possible combinations of visual and auditory stimuli. The qualities of these stimuli were kept constant, but their location and organization changed according to the specific experimental objective. The information of the visual sensory system either supported or conflicted with the auditory system.

The following chapters will include a detailed description of the subjects, apparatus and methodology employed in the experiments as well as the results with a tentative interpretation.

CHAPTER II - METHODOLOGY

(i) SELECTION OF STIMULI AND EXPERIMENTAL CONDITIONS.

I want to start this chapter on methodology by mentioning remarks made by other researchers relating to the methodology used in their works.

Special difficulties are encountered where subjects are newborn infants. Observations must be limited to those brief periods when the child in the first 5 days of life is awake, alert and not crying. For research in vision he must also be open-eyed. Additionally, it is difficult to introduce stimuli to which the infant is responsive, but which do not startle. The criteria for participation in the study required subjects considered normal babies. They are to be full term neonates (38-42 weeks gestation), with a birth weight higher than 2500 grs., and with no major pre-natal or post-natal complications. The mother should be at the test site in close proximity to the newborn infant. The room temperature should be warm (Haith 1966; Turkewitz et al 1966; Alegria and Noirot 1978; Ashton 1971).

The most important variables in eliciting reliable eye turning responses to sound are the methods used in handling the newborn and the nature of the auditory and visual stimuli used (Turkewitz et al 1970). Greater general activity occurs neither under moderate intensities of visual stimulation nor in complete darkness, but under minimal light conditions. Studies show that overt responses are greater if the stimulus is short, whereas there may be inhibition of activity or complete lack of response if the stimulus is of too long a duration (Irwin and Weiss 1930). Ling (1942) added that the strong illumination used in her study had a somewhat retarding effect on the fixation and postural responses of the infants below 4 weeks of age.

Turkewitz et al (1966) concluded from their experimental work that directional responding is a function of effective stimulus intensity. A relatively low level of arousal and a relatively less intense stimulus each resulted in turning towards an auditory stimulus. More intense stimulation produces a reduction in the incidence of this turning.

With respect to the visual stimuli, Hittelman and Dickes wrote in 1979 that the visual gestalt of 2 eyes and a forehead is one of the most effective stimuli for eliciting a social smile in the infant. In addition, infants fixate on the eyes, not on the mouth of the person speaking to them. In relation to the distance at which the visual stimuli should be placed, Haynes et al (1965) and Carpenter (1974) found that the newborn would fixate his eyes on targets at a particular distance; a median of 20 cm. (8 inches). Images of targets nearer or further away were proportionally blurred, gradually becoming sharper. Adult vision is reached at approximately 4 months. Salapatek and Kessen (1966) tell us that the newborn infant showed a widely dispersed scanning in the horizontal rather than in the vertical dimension.

The infants responded better to auditory stimuli which had the fundamental frequencies within the range of the human voice (Carpenter 1974).

These are some of the pieces of evidence from different experimenters that helped in evaluating the selection criteria of particular stimuli and experimental conditions relevant to the experiments reported in this thesis.

(ii) <u>M E T H O D.</u>

A period of training took place to allow the experimenter to become familiar with the technical equipment and in order to make sure that the stimuli situation was the most appropiate, before the experimental situation was clearly defined. During this definition period it was decided that the best arousal state of newborn babies was just after being fed and changed; the best posture for clearer filming was sitting up, and bright lights should be removed to avoid eye closure. It was also observed that repeated auditory stimulation of more than 80 db. quite often made the babies cry. (Not surprising, as it is pretty loud).

Certain experimental techniques had also to be adapted because it was thought that the mothers could influence the babies' movements by involuntarily pushing or pressing one side of the babies' bodies. While still in the training period, some of the mothers were asked to wear a pair of headphones through which music was played. The babies' activities were compared with those whose mothers did not wear headphones. As no difference was found in the subjects' responses, the earphones were not considered necessary for the experimental sessions.

It was found to be very difficult for the researcher to keep a close watch of the babies' face and simultaneously operate the apparatus efficiently. Therefore the experimenter filmed the experimental sessions to allow a later analysis of subjects' responses and avoid the presence of 2 researchers in the laboratory, which could have provided too many extra clues to which the baby might respond. These responses were later replayed and scored objectively.

The following procedure shows the steps that were adopted after this initial period of training and is the one used for all the experiments mentioned in this thesis where the subjects are newborn babies.

(ii)a) <u>Newborn Experimental Subjects.</u>

At the beginning of each day the experimenter approached the sister in charge of the wards at Southampton General Hospital Maternity Unit. The sister informed her of new arrivals and which babies had medical or social problems. The experimenter then checked the babies' records and selected possible experimental subjects. Those babies who were under 7 days old and born by pelvic route were observed in the wards. The mothers of those infants who were just fed, changed and still awake were approached. It was explained to the baby's mother that the objective of the study was to find out more about the reactions of babies to a sound and that their babies' responses were to be video-taped. If they agreed to take part, they were offered the opportunity to watch the pictures of their babies in the small monitor of the camera immediately after the session was finished.

The newborn babies with their mothers always present were pushed in their cots to the experimental laboratory which was a small room adjacent to Southampton General Hospital Maternity Unit. The room measured 3.00 m. x 2.50 m. with an ambient noise level of 40 db ± 10.0 db and a temperature of 22° C. ± 2° C.

The experiments took place between 10.15 and 11.45 hrs. in the mornings and between 14.15 and 15.00 hrs. in the afternoons.

For insurance reasons only the mother was allowed to hold the baby. On entering the laboratory the mother was asked to sit down, hold the baby straight on her lap facing the camera. The experimenter checked that the baby's visual field was completely enclosed by the white cloth screen. The mother was asked to hold the baby firmly without obstructing the ears and remain still all through the session.

The length of the experimental session had to be such as to allow experimental manipulation, but not to last more than 6 minutes, as the babies would become tired and lose concentration.

All the experimental subjects had one session each with a total of 40 trials. Each trial consisted of a sound of 1 second's duration.

The babies were allowed approximately 1 minute to explore and become familiar with the visual environment (a baseline period). There was no auditory stimulus during this period.

After the baseline period, the first auditory stimulus was given. If the baby did not produce an eye movement, the experimenter waited for 30 seconds and gave the next sound (and so on until finishing the 40 trials). If the neonate produced an eye movement contingent with the sound, the experimenter waited until the baby's face returned to the centre of the visual field and his/her eyes were facing the middle of the visual field before the next auditory stimulus was played. If after 30 seconds the experimental subject did not return its eyes to the centre of the visual field, the next auditory stimulus was given regardless.

The locus of the sound and the characteristics of the visual stimuli varied according to the experimental design.

All the mothers but one agreed to take part in the study. One of the problems in working with newborn babies is that they sleep most of the day. To obtain our final sample of 80 such babies, an initial sample of 238 experimental subjects was used. Of these, 76 fell asleep while being pushed in their cots between the ward and the laboratory, 45 fell asleep at the beginning of the experiment, 28 cried before/during the experiment and 9 could not be included because of the poor quality of the picture due to malfunctioning or mishandling of the technical equipment.

When the session was finished the mothers watched the part of the video film that referred to their babies and then they were taken back to their wards.

The conditions, settings, instructions and experimenter were the same for experiments where the subjects were newborn babies and for the cross-sectional study where the subjects were older babies, even though the laboratory for the older group of experimental subjects was in a different part of the town.

(ii)b) <u>Older Experimental Subjects.</u>

For groups 2, 3, 4 and 5 of Experiment IV in the cross-sectional study (where the experimental subjects were older children), the procedure followed with the mothers was slightly different even though the experimental subjects' manipulations were the same. The parents of the possible experimental subjects were contacted by post and invited to attend the laboratory with their children. Enclosed in the posting were a brief summary of the work done so far, an explanation of the study in which their baby was asked to take part and a suggested appointment time . A self-address stamped envelope was also enclosed. If the mothers wanted to take part but could not manage the suggested time, another date was arranged. The mothers who wanted to take part but found the journey by bus too difficult were offered the opportunity of being picked up by car. Once the mothers arrived with their babies at the laboratory, the explanations and instructions given to them were exactly the same as those given to the mothers of the newborn experimental group. A small room with toys was provided next door where siblings could stay.

The laboratory was a room of 3.00 m. x 3.00 m., in the Psychology Laboratory which is housed in an annex of Southampton University. The ambient noise level was

37 db ± 5 db, and the temperature was 21° C.± 3° C. The experiment took place between 14.00 and 17.00 hrs. in the afternoon.

To obtain a final sample of 32 older experimental subjects, 67 appointments were sent. Seven parents did not reply, 8 answered but declined to take part in the study, 5 did not turn up at the agreed appointment or when they were to be picked up were not at home, 7 babies fell asleep during the experiment, 4 cried, 2 babies' video tapes were out of focus, 1 baby had a different age to the one given by the mother when registered and 1 was permanently distracted by a crying sibling.

The mother was invited to watch her baby on the monitor of the camera at the end of the session .

(iii) <u>S C O R I N G</u>

The transcription of the video tapes into measurable responses was found to be a long and complicated job. The videos were watched separately by two judges (one of them the experimenter), who knew only that there had been a sound, but could not tell its location. The judges had to decide:

a) if there was an eye movement (defined as a movement of the pupils towards the right or left after the sound and contingent with it within 6 seconds of its appearance).

b) The direction of the eye movement.

For example, if the eyes had already moved to the left or moved left before the sound was played, an eye movement was recorded only if the eyes went further to the left, or if they went back to the middle line and then moved to the left again.

The tapes were played on a SONY VIDEO Recorder (AV 36 O CE) machine connected to a SHIBADEN MONITOR TV 201-1C, 18.4 square inch screen.

The two judges watched each baby's video 3 times separately and then once more together. The final score for each baby only included agreed responses by the two judges. The final agreement was 91%. After the scoring, the agreed responses were compared with the original pattern of auditory stimuli given to each baby. The information was registered in the babies' cards, together with their personal details and to which of the experimental conditions they were assigned.

The agreed responses for each experimental subject provided the following data:

a) the total number of responses given by each baby out of a possible total of 40 stimuli received.

b) The number of correct and incorect responses produced by the baby (eye movements ipsilateral or contralateral with the locus of the sound).

The results for each baby were expressed as a proportion: the number of correct responses over the number of total responses given by the experimental subject.

(iv) CHARACTERISTICS OF THE EXPERIMENTAL SUBJECTS.

(iv)a) Newborn Babies.

The experimental subjects had to be so young that their answers could not have been learned but should be their innate reactions, following the hypothesis set up at the beginning of this thesis.

The selection criteria required for these experimental subjects was that they should be newly born babies with the following group characteristics:

- born by pelvic route.
- to include both sexes,
- maximum 7 days old. (There was no minimum age for the babies, but the mother had to be able to walk),
- just fed and changed,
- awake,

The group elimination criteria were:

- medical contraindications,
- social contraindications,
- complicated labour.

The Maternity Unit of Southampton General Hospital was chosen as the setting for the studies as babies of this age are on the whole still in hospital. All the newborn babies selected as experimental subjects were at that time patients in this establishment. The mothers' agreement was requested for the babies to be included in the studies.

A sample of 80 experimental subjects was selected to take part in the studies with newborn babies. They were of both sexes and their ages varied between 7 and 168 hours.

The experimental subjects were allocated to 4 experiments.

The group characteristics of the newborn subjects are given in Table 1.

Table 1, Exp. IV: Characteristics of newborn experimental subjects.

	N	SEX		AGE	
		M	F	$\bar{X} \pm SD$ in hours	range in hours
exp I	36	20	16	77 ± 41	140
exp II	24	8	16	44 ± 26	98
exp III	12	7	5	37 ± 19	50
exp IV group 1	8	2	6	30 ± 18	50

(iv)b) Older Infants.

Thirty two experimental subjects of both sexes were selected whose ages ranged between 6 and 29 weeks. These subjects were included in experiment IV, a cross-sectional study measuring the development of babies' responses.

The group selection criteria were similar to those described previously except that children of a given age were selected according to the requirements of the experimental design.

The group elimination criteria were similar to those used for the previous experiments.

The older experimental subjects for experiment IV were selected from a volunteer bank of babies whose parents had originally registered in the Department of Psychology of Southampton University as a result of radio programmes and newspaper articles relating to the study of early child development. The parents were invited to come to the University and take part in the study.

These subjects were allocated to any one of the 4 groups according to their ages. The group characteristics of these older experimental subjects by age are given in Table 2.

Forty experimental subjects took part in this experiment, 8 of them newborn and the rest older infants.

Table 2, EXP.IV: <u>Characteristics of older experimental subjects.</u>

	N	SEX		AGE	
		M	F	X ± SD in weeks	range in weeks
group 2	8	5	3	7 ± 2	4
group 3	8	4	4	13 ± 1	3
group 4	8	6	2	19 ± 1.5	4
group 5	8	5	3	27 ± 3	7

<u>Notes</u> :

The characteristics of the newborn experimental subects of group 1 are given in Table 2, together with the other newborn babies.

(v) APPARATUS.

A white cloth screen with ceiling and walls enclosing the subject's visual field was designed to assure that the experimental subject's visual field was homogeneous, and completely controlled by the experimenter. The camera lens was fixed behind a hole made at the centre of the screen at the subject's eye level.

The visual field could be structured by one or two cards each carrying two red discs of 2 cm. diameter and 2 cm. apart, to give the experimental subject visual cues (a schematic representation of 2 eyes). The cards were placed at the baby's eye level at a distance of 30 cm. to the right or left of the midline and at an angle of 22° with respect to the baby's face (see Figure 1). The room was provided with dim illumination from a shielded light source to allow the newborn babies to fully open their eyes .

The auditory stimulus was produced on an electronic oscillator (type LFM Farnell average 450 Hz frequency sine wave). The intensity of the sound was 62 db and of 1 second's duration. This kind of auditory stimulus resembles the human females voice if reproduced electronically. The oscillator was connected to a switchbox fixed in an appropriate place to enable the experimenter to generate the audio stimulus (a beep) and send it to either of two separate loudspeakers.

The loudspeakers were placed to the right and the left of the baby's face behind the white cloth screen and behind the locus where the visual stimuli could be placed.

As mentioned before, all of the experimental sessions were video-taped in order to avoid interference by the experimenter's trying to observe and record the baby's reaction to the auditory-visual stimulation, and to allow a more detailed analysis of the experimental subject's reactions.

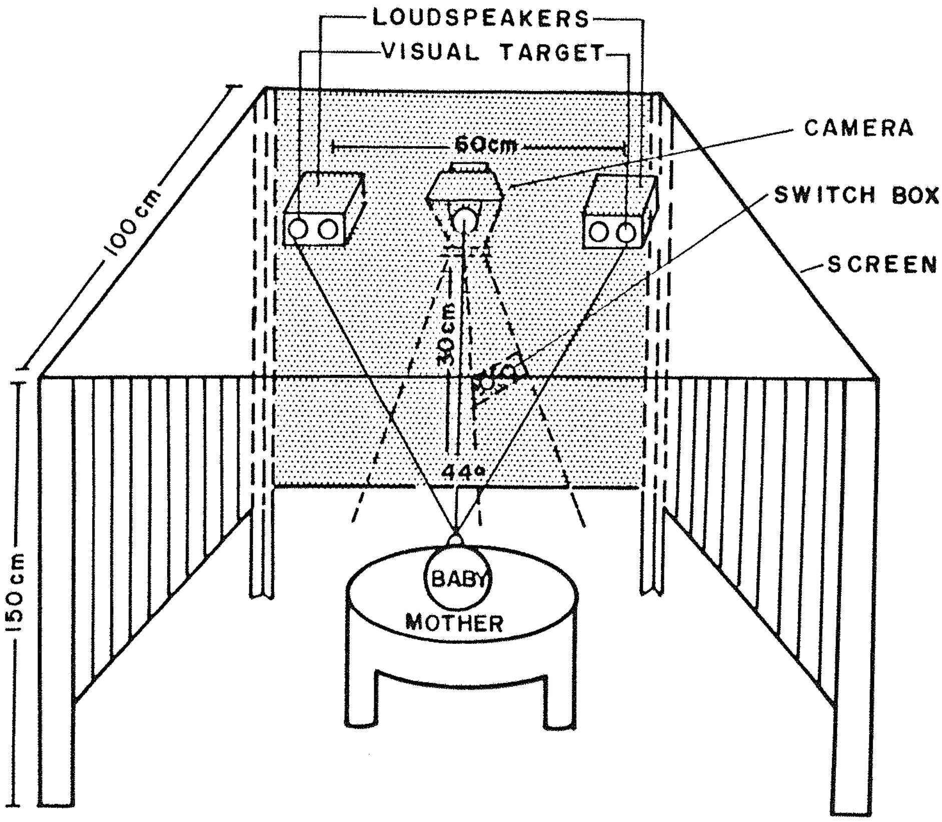
All the filming equipment was hidden from the experimental subject by the screen. The camera was switched on prior to the first auditory stimulation and was switched off after the 40 trials were finished.

The apparatus used to do the filming was a SONY VIDEO Recorder (AVC 3420 CE), fitted with a silicone diode tube sensitive to semidarkness.

The zoom (SONY TV zoom lens 1:1.8 close up) was left open to obtain a clear picture of the baby's eyes.

The apparatus and the experimenter remained unchanged for all the experimental subjects throughout the experimental process.

Fig. 1. APPARATUS AND SETTING DIAGRAM



(v) EXPERIMENTAL DESIGN.

A series of experiments was designed to observe and measure the responses of newborn and older babies to a variety of audio-visual stimuli.

The newborn experimental subjects were randomly assigned to one of the experimental conditions throughout the study.

Six patterns of audio-visual stimulation were established to implement the six different experimental conditions. They are described in Table 3.

Table 3. Experimental conditions for the study of audio-visual responses.

Experiment.	Condition.	Stimulus pattern.	Organization of the session.	Graphical representation of the experimental subjects' perceptual field.
I AND II	Condition I-1: Sound only in in blocks.	Left auditory stimuli and Right auditory stimuli.	4 blocks of 10 acoustic trials each and no visual stimuli.	[audio] [audio]
	Condition I-2: Congruent.	Left auditory stimuli and left visual stimuli and Right auditory stimuli and right visual stimuli.	4 blocks of 10 acoustic trials each and one visual stimulus congruent with the locus of the sound.	[audio visual] [audio visual]
	Condition I-3: Incongruent.	Left auditory stimuli and right visual stimuli and Right auditory stimuli and left visual stimuli.	4 blocks of 10 acoustic trials each and one visual stimulus incongruent with the locus of the sound.	[vis. audio] [vis. audio]
III	Condition III-1: Sound in blocks and 2 permanent visual stimuli.	Left auditory stimuli and left and right visual stimuli and Right auditory stimuli and right and left visual stimuli.	4 blocks of 10 acoustic trials each and two visual stimuli permanently present.	[vis. vis. audio] [vis. vis. audio]
IV	Condition IV-1, ST: Sound at random and 2 permanent stimuli.	Left auditory stimuli and left and right visual stimuli and Right auditory stimuli and right and left visual stimuli.	40 acoustic random trials and two visual stimuli permanently present.	[vis. vis. audio] [vis. vis. audio]
	Condition IV-2, BL: Sound only random.	Left auditory stimuli and Right auditory stimuli.	40 acoustic random trials and no visual stimuli.	[audio] [audio]

CHAPTER III - EXPERIMENT I   Page

(i) I N T R O D U C T I O N.

Experiment I was designed to evaluate the response of newborn exprimental subjects to different conditions of audio-visual stimulation.

It was decided that this, the first experiment, should be aimed at measuring basic sensory functioning with relation to the auditory and visual senses. Three simple paradigms of stimulation were chosen; they were called conditions.

(ii) M E T H O D.

The pattern of auditory stimulation was kept constant. Sounds were presented in blocks of 10 trials to the right (R) or left (L) of the subject's visual field. Half the subjects would receive a RLRL pattern of stimuli, and the other half a LRLR pattern (see Table 3). The experimental variable that was manipulated was the structure of the visual field which was presented according to the following conditions:

- Condition I-1; or sound only in blocks group. The experimental subjects were given 40 trials while facing a blank visual field.

- Condition I-2; or congruent. The experimental subjects were given 40 trials in which the locus of the audio stimulus was congruent with the locus of the visual stimulus.

- Condition I-3; or incongruent. The experimental subjects were given 40 trials in which the audio stimulus came from the opposite locus of the visual field to that of the visual target.

(iii) <u>E X P E R I M E N T A L   S U B J E C T S.</u>

The experimental subjects were selected from babies at Southampton General Hospital Maternity Unit. They had to be normal full term babies of not more than 7 days old. For a detailed description of the method and selection of experimental subjects, see section (iv) Chapter II.

Thirty six experimental subjects were randomly assigned to each of the 3 experimental conditions. Their average age was 77 hours with a standard deviation of 41 hours and range of 140 hours.

The characteristics of the 36 experimental subjects are described in Table 4.

Table 4, Exp. I: <u>General characteristics of the sample.</u>

N	SEX		APGAR		BIRTH WEIGHT grs		BIRTH ORDER		LENGTH OF LABOUR hrs		DRUGS		
	M	F	x̄±SD	range	x̄±SD	range	x̄±SD	range	x̄±SD	range	no	1	2
36	20	16	7±2	7	3346 ±460	1700	2±1	5	7±7	22	7	23	6

Notes : Drugs

no = no drugs

1 = Pethidine, Entonox, Phenergon, Valium, Sparine, etc.

2 = Epidural plus any other drugs.

The experimental subjects selected were of both sexes. They were in a normal healthy condition (indicated by their average one minute Apgar of 7). The rest of the subjects' characteristics seemed to be similar to the ones observed in normal babies delivered in hospital.

(iv) R E S U L T S

(iv)a) Analysis of the Individual Data.

The figures in the following tables are the results of the analysis of the individual experimental subjects' responses in Experiment I.

Tables 5, 6 and 7 represent the general data for each of the experimental subjects who took part in this experiment. Subjects were grouped according to the experimental conditions they were given.

Each box includes the percentage of correct responses given in a block of 10 trials. A correct response, as defined previously in the methodology chapter, is defined as an eye movement displayed in the same direction as the locus of the sound. The figures in brackets represent the absolute number of correct and total responses per ten trial block (correct/total).

The total column represents the equivalent percentage for the sum of all correct responses in the trials, i.e., four blocks of ten trials each. The figures in brackets are the absolute total of correct and total responses per set of 4 blocks of 10 trials (correct/total) for each individual subject.

The binomial test was applied to test the significance of these values.

Table 5, Exp. I: <u>Individual audio-visual responses when the visual stimulus was absent and the sound given in blocks of 10 trials (condition I-1, sound only).</u>

	T R I A L S				
experimental subjects	1-10	11-20	21-30	31-40	TOTAL
1	67% (6/9)	40% (2/5)	17% (1/6)	100% (3/3)	52% (12/23)
2	57% (4/7)	50% (4/8)	43% (3/7)	50% (5/10)	50% (16/32)
3	71% (5/7)	40% (4/10)	67% (6/9)	14% + (1/7)	48% (16/33)
4	62% (5/8)	55% (5/9)	37% (3/8)	40% (4/10)	48% (17/35)
5	62% (5/8)	37% (3/8)	33% (1/3)	0% (0/0)	47% (9/19)
6	17% (1/6)	57% (4/7)	50% (4/8)	80% (4/5)	50% (13/26)
7	20% (1/5)	25% (2/8)	80% (4/5)	87% * (7/8)	54% (14/26)
8	0% ** (0/8)	100% ** (10/10)	22% + (2/9)	86% + (6/7)	53% (18/34)
9	50% (3/6)	62% (5/8)	62% (5/8)	0% (0/4)	50% (13/26)
10	83% (5/6)	33% (2/6)	33% (2/6)	62% (5/8)	54% (14/26)
11	28% (2/7)	80% (4/5)	43% (3/7)	50% (3/6)	48% (12/25)
12	40% (2/5)	100% * (6/6)	0% * (0/6)	28% (2/7)	42% (10/24)

* p < 0.05)   ** p < 0.01)   + 0.05 < p < 0.10 tendency

It can be seen from Table 5 that there are no experimental subjects who show significantly more eye movements in either direction over the 40 trials in the group which was given condition I-1 (sound only in blocks). Subject 8 has significantly more eye movements in one direction in blocks 1-10 and 11-20 but as can be seen from the table, the direction of the eye movements remains the same for the 40 trials. Subject 12 presents a similar pattern for the second and third block of trials.

Table 6, Exp. I: Individual audio-visual responses, when the visual stimulus was congruent and the sound given in blocks of 10 trials (condition I-2, congruent).

	TRIALS				
experimental subjects	1-10	11-20	21-30	31-40	TOTAL
1	78% + (7/9)	37% (3/8)	67% (4/6)	20% (1/5)	54% (15/28)
2	50% (5/10	90% * (9/10)	30% (3/10)	71% (5/7)	59% (22/37)
3	100% ** (8/8)	17% (1/6)	0% (0/0)	33% (2/6)	55% (11/20)
4	71% (5/7)	43% (3/7)	83% (5/6)	50% (1/2)	64% (14/22)
5	78% + (7/9)	67% (6/9)	0% ** (0/8)	100% ** (8/8)	62% (21/34)
6	100% * (5/5)	83% (5/6)	67% (4/6)	67% (2/3)	80% ** (16/20)
7	40% (4/10)	50% (4/8)	62% (5/8)	67% (6/9)	54% (19/35)
8	22% + (2/9)	62% (5/8)	78% + (7/9)	71% (5/7)	58% (19/33)
9	86% + (6/7)	80% (4/5)	100% (2/2)	0% (0/0)	86% ** (12/14)
10	0% * (0/6)	86% + (6/7)	60% (3/5)	100% (4/4)	59% (13/22)
11	55% (5/9)	60% (3/5)	87% * (7/8)	71% (5/7)	69% * (20/29)
12	86% + (6/7)	50% (3/6)	80% (4/5)	67% (4/6)	71% * (17/24)

* $p < 0.05$) ** $p < 0.01$) + $0.05 < p < 0.10$ tendency

It can be observed in Table 6 that the group which was given a congruent stimuli pattern in the first block of 10 trials contains three out of twelve subjects (subjects 3, 6 and 10) who show significantly more eye movements in one direction and five other subjects show a clear tendency. Of these eight subjects, six showed responses that are ipsilateral with the sound.

Four experimental subjects (subjects 6, 9, 11 and 12) show significantly more eye movements in one direction over the 40 trials. These movements are ipsilateral with the sound and the visual stimulus.

Table 7, Exp. I: Individual audio-visual responses, when the visual stimulus was incongruent and the sound given in blocks of 10 trials (condition I-3, incongruent).

	TRIALS				
experimental subjects	1-10	11-20	21-30	31-40	TOTAL
1	57% (4/7)	25% (2/8)	60% (3/5)	25% (1/4)	42% (10/24)
2	100% * (6/6)	0% * (0/5)	50% (3/6)	0% (0/3)	45% (9/20)
3	0% ** (0/7)	57% (4/7)	20% + (2/10)	50% (3/6)	30% (9/30)
4	40% (2/5)	43% (3/7)	25% (2/8)	40% (2/5)	36% (9/25)
5	0% ** (0/9)	100% * (6/6)	0% ** (0/7)	0% (0/0)	27% (6/22)
6	86% + (6/7)	43% (3/7)	50% (3/6)	0% ** (0/7)	44% (12/27)
7	67% (6/9)	44% (4/9)	0% * (0/6)	50% (3/6)	43% (13/30)
8	50% (4/8)	40% (4/10)	43% (3/7)	28% (2/7)	41% (13/32)
9	33% (3/9)	57% (4/7)	50% (4/8)	17% (1/6)	40% (12/30)
10	28% (2/7)	0% * (0/5)	0% ** (0/8)	33% (3/9)	17% (5/29)
11	0% (0/2)	50% (1/2)	25% (1/4)	0% (0/0)	25% (2/8)
12	0% ** (0/8)	89% * (8/9)	0% ** (0/7)	100% (2/2)	38% (10/26)

* $p < 0.05$) ** $p < 0.01$) + $0.05 < p < 0.10$ tendency

It can be observed in Table 7 that the group which was given an incongruent stimuli pattern in the first block of 10 trials contains four subjects (subjects 2, 3, 5 and 12) who display significantly more eye movements in one direction; three contralateral and one towards the sound. Subjects 29 and 36 repeated the same direction of their eye movements for the first 30 trials. In the second block of 10 trials (11-20) four subjects (subjects 2, 5, 10 and 12) show significantly biased eye movements, two towards and two away from the direction of the sound. In the third block, four subjects (subjects 5, 7, 10 and 12) show significantly more eye movements in one direction and subject 3 also shows a tendency. All these subjects displayed a bias contralateral with the direction of the sound.

Three experimental subjects (subjects 3, 5 and 10) show significantly more eye movements in one direction over the 40 trials. In this case, the bias shown is contralateral with the sound, i.e. towards the visual stimulus.

An analysis was also carried out of data relating to the direction of the experimental subjects' responses to the first trial (the first auditory stimulus given to each subject) and to the direction of the first response given by each subject irrespective of whether it was given to the first, second or third trial. The results are shown in Table 8, where each box of the first trial row contains the total number of experimental subjects over a total possible of twelve per condition, who responded to the first trial of the experimental session. The box indicates the direction of the eye movement in relation to the sound.

Each box of the first response row contains the total of experimental subjects who displayed biased eye movements in relation to the sound over a total of twelve per condition, whenever their first response occurred.

Table 8, Exp. I: Individual analysis of the eye movements' direction.

		Towards sound	Away from sound	Total
Sound only condition	{first trial	4/12	5/12	9/12
	{first response	5/12	7/12	12/12
Congruent condition	{first trial	4/12	7/12	11/12
	{first response	4/12	8/12	12/12
Incongruent condition	{first trial	5/12	7/12	12/12
	{first response	5/12	7/12	12/12
TOTAL Exp. I	{first trial	13/36	19/36	32/36
	{first response	14/36	22/36	36/36

It can be seen from Table 8 that slightly more eye movements (though not significantly more) are displayed away from the sound in the first trial and the first response under all the conditions. Eighty nine percent of the subjects responded to the first trial of the experimental session.

(iv)b) Perseverance.

Perseverance was studied with the aim of ascertaining whether the eye movements occurred in relation to the locus of the sound or whether the sound acted rather as a trigger for the eye movement.

The results of this experiment were re-analysed to find out if the experimental subjects in any way showed that they persevered in the direction of their eye movements.

To this end the responses of the experimental subjects were re-scored taking as correct responses the eye movements in subsequent responses in the same direction as that of the first response (Table 9). Eye movements in subsequent responses in the same direction as that of the first response after each change of auditory locus, i.e. following trials 1-11-21 and 31 (Table 11) were also considered correct. The experimental subjects were considered to have shown perseverance if they had significantly more ($p<0.05$) eye movements towards the direction of the first response, as previously described.

Each box contains the number of experimental subjects who persevered or did not persevere over a possible twelve per condition (subjects who persevered/12).

Table 9, Exp.I: Perseverance by individual experimental subjects.

	Exptal. subjects who persevered			Exptal. subjects who did not persevere			Total who persevered	Total who did not persevere
	sound only	congruent	incongruent	sound only	congruent	incongruent		
*1	1/12	3/12	4/12	11/12	9/12	8/12	8/36	28/36
*2	3/12	3/12	5/12	9/12	9/12	7/12	11/36	25/36

Notes :

*1 First ten trials taking as correct criteria the first response given by the experimental subject.

*2 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

Eight experimental subjects persevered in the first 10 trials, four of these being from the incongruent condition. Eleven subjects persevered over all 40 trials.

The next table, Table 10, gives the direction in which the experimental subjects persevered in relation to the locus of the first sound. Each box gives the total number of experimental subjects who persevered towards or away from the first sound out of the total per condition (number of subjects who persevered towards or away from the sound/12).

Table 10, Exp. I: <u>Direction of the individual experimental subjects' perseverance, following the first response.</u>

	Towards the locus of the first sound			Away from the locus of the first sound			TOTAL	
	sound only	congruent	incon-gruent	sound only	congruent	incon-gruent	toward first sound	away from first sound
*1	0/1	2/3	1/4	1/1	1/3	3/4	3/8	5/8
*2	0/3	1/3	1/5	3/3	2/3	4/5	2/11	9/11

Notes :

*1 First ten trials taking as correct criteria the first response given by the experimental subject.

*2 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

Three subjects persevered towards the locus of the first sound and five away from it during the first 10 trials and under the 3 conditions. Over the 40 trials, two subjects persevered ipsilaterally with the first sound and nine contralaterally. Significantly ($p<0.05$) more contralateral perseverance over the 40 trials can be observed.

Table 11, Exp. I: Perseverance by individual subject after each change.

	Exptal. subjects who persevered			Exptal. subjects who did not persevere			Total who persevered	Total who did not persevere
	sound only	congruent	incongruent	sound only	congruent	incongruent		
*1	3/12	5/12	6/12	9/12	7/12	6/12	14/36	22/36

Notes:

*1 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

Fourteen subjects showed perseverance when each change in direction of auditory stimuli is taken into account.

The incongruent group contains the largest number of subjects who showed perseverance, followed by subjects in the congruent and then sound only groups.

The results with respect to the direction of the eye movements for the 14 experimental subjects who persevered after each change of direction of the audio stimulus are given in Table 12.

Each box contains the number of blocks of 10 trials each during which the experimental subject persevered either towards or away from the locus of the sound. The divisor figure is the total of blocks of trials during which perseverance occurred after the change of direction of auditory stimulus. (i.e data described as number of blocks where perseverance occurred towards or away from the sound/number of blocks where perseverance occurred). The total number of blocks of trials showing perseverance were as follows: 12 in the sound only group (given by three subjects who persevered, with 4 blocks each), 20 in the congruent group (given by 5 subjects who persevered, with 4 blocks each), and 24 in the incongruent group (given by the six subjects who persevered, with 4 blocks each).

Table 12, Exp. I: <u>Direction of the eye movements of the individual experimental subjects who persevered after each change.</u>

	Number of blocks of 10 trials towards the locus of the sound			Number of blocks of 10 trials away from the locus of the sound			TOTAL	
	sound only	congruent	incon-gruent	sound only	congruent	incon-gruent	toward	away
*1	5/12	12/20	7/24	7/12	7/20	16/24	24/56	30/56

<u>Notes</u> :

*1 Over all 40 trials, taking as correct criteria the first response given by the experimental subject after each change, i.e. in trials 1 - 11 - 21 and 31.

*2 In both the congruent and incongruent conditions there was one experimental subject who did not give any response in one of the blocks of 10 trials.

The experimental subjects who show perseverance after each change reflect a different pattern of responses according to the condition they were presented. The sound only group (condition I-1) looked slightly more away from the locus of the sound. The congruent group (condition I-2) looked slightly more towards the sound. Neither of these groups' responses was significantly biased. The incongruent group (condition I-3) looked significantly more ($p < 0.05$) away from the locus of the sound, i.e. towards the visual stimulus.

(iv)c) Analysis of the Grouped Data.

The next table, Table 13, analyses the results of the 36 experimental subjects as a group, summing up all the experimental subjects' responses. Each box shows (in brackets) the total number of sound contingent oculomotor responses ipsilateral and contralateral to the sound, in each of the three conditions.

Table 13, Exp. I: Grouped data, number of sound contingent oculomotor responses for the three experimental conditions: condition I-1, sound only; condition I-2, congruent and condition I-3, incongruent.

	Number of responses		
*1	Sound only	Congruent	Incongruent
Ipsilateral	(164) 50%	(199) ** 63%	(110) ** 36%
Contralateral	(165) 50%	(119) ** 37%	(193) ** 64%
TOTAL	(329)	(318)	(303)

** $p < 0.01$

Note :

*1 Eye movements with respect to the sound.

As can be seen in Table 13, in the congruent condition, the significant majority of eye movements are ipsilateral to the sound (and to the visual target, $p < 0.01$). In the incongruent condition the eye movements are spatially contralateral to the sound (and towards the visual target, $p < 0.01$). In the sound only condition half the eye movements were towards the sound and the other half away from it.

The next table, Table 14, also analyses the results of the 36 experimental subjects as a group divided into 3 conditions. It gives the sum of all the experimental subjects' responses per condition, but divided into the four blocks of trials. Each box gives the percentage of correct responses over the total responses for all subjects, per block of 10 trials per condition. The total column represents the percentage of correct responses of the total responses given for all the experimental subjects over all the trials. The figures in brackets represent the absolute number of correct responses over the absolute number of total responses given in each block of 10 trials (number of correct responses/number of total responses). The figures in brackets in the total column give the absolute total number of correct responses over the total responses given for all the experimental subjects over all the trials (correct/ total). The binomial test was applied to test the significance level.

Table 14, Exp. I: Grouped data of audio-visual responses, by blocks of 10 trials for the three experimental conditions: condition I-1, visual stimuli absent sound only; condition I-2, visual stimuli congruent and condition I-3, visual stimuli incongruent.

Trials	1-10	11-20	21-30	31-40	TOTAL
Sound only	48% (39/82)	57% (51/90)	41% (34/82)	53% (40/75)	50% (164/329)
Congruent	62% ** (60/96)	61% * (52/85)	60% * (44/73)	67% ** (43/64)	63% ** (199/318)
Incongruent	39% * (33/84)	46% (39/85)	27% ** (21/79)	31% ** (17/55)	36% ** (110/303)
TOTAL	50% (132/262)	55% (142/260)	42% (99/234)	52% (100/194)	50% (473/950)

* $p < 0.05$) ** $p < 0.01$)

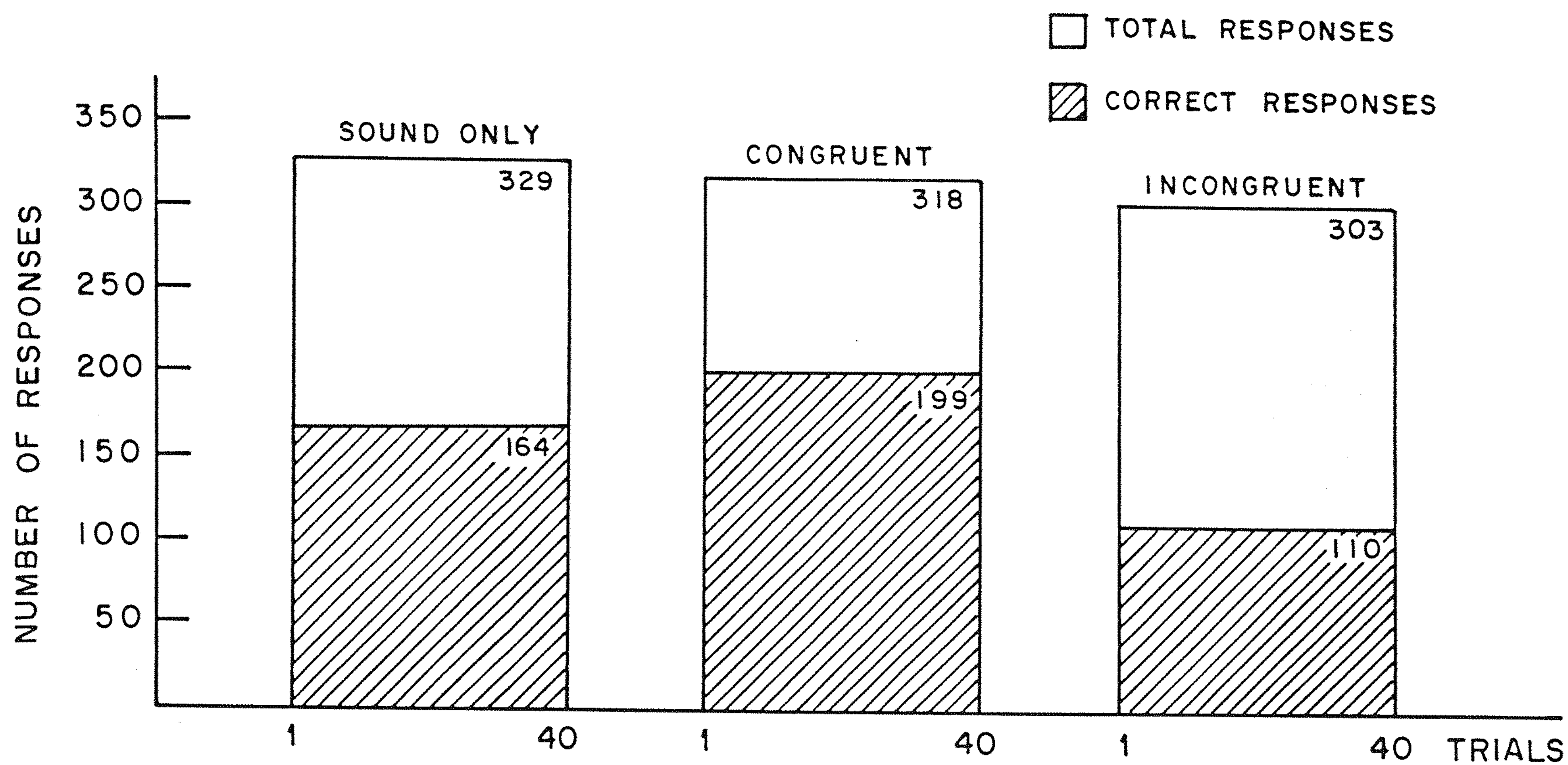
It can be seen from Table 14 that approximately half the responses to the sound are given in either direction for the sound only group. This pattern of responses is equal to chance, and is maintained throughout the 4 blocks of trials. The pattern is the same for the total of 40 trials. Experimental subjects in the congruent group give significantly more responses ipsilaterally with the locus of the sound in all the 4 blocks of the session. Over the 40 trials the responses are significantly more ipsilateral with the sound. Those experimental subjects in the incongruent group give eye movements significantly more contralaterally with the locus of the sound in 3 of the 4 blocks of 10 trials, and also over the total of 40 trials.

Fig. 2 gives a graphic representation of the total column of Table 14. It shows the total and correct number of responses for the 40 trials in each condition.

Fig. 3 gives a graphic representation of the contents of Table 14. It uses the figures in brackets, that is the total correct out of the total responses per block of 10 trials in each condition.

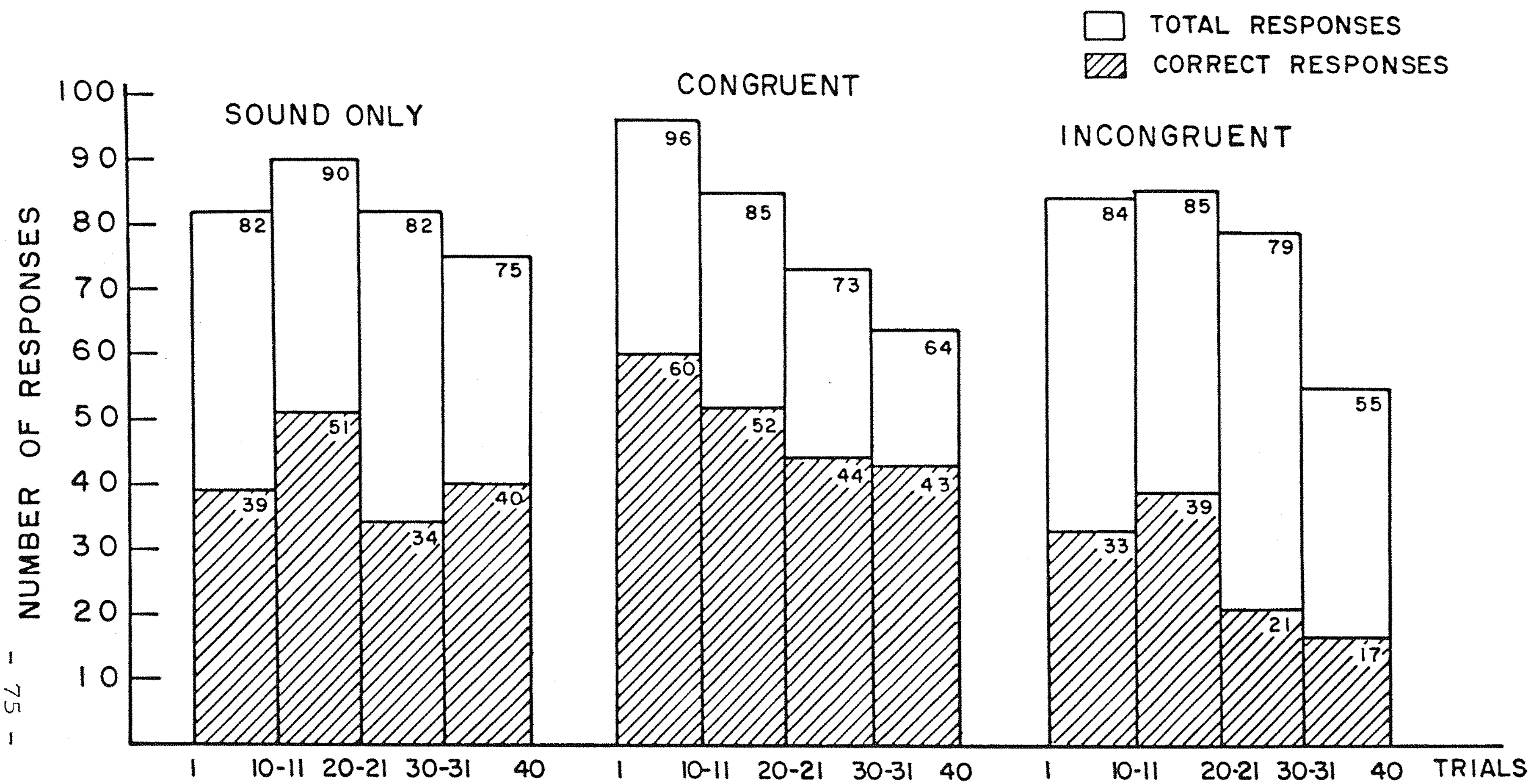
Fig. 4 also gives a graphic representation of the data in Table 14, but in a proportional form.

Fig. 2, Exp. I: Grouped data, total and correct audio-visual responses in the three experimental conditions: condition I-1, sound only; condition I-2, congruent and condition I-3, incongruent.



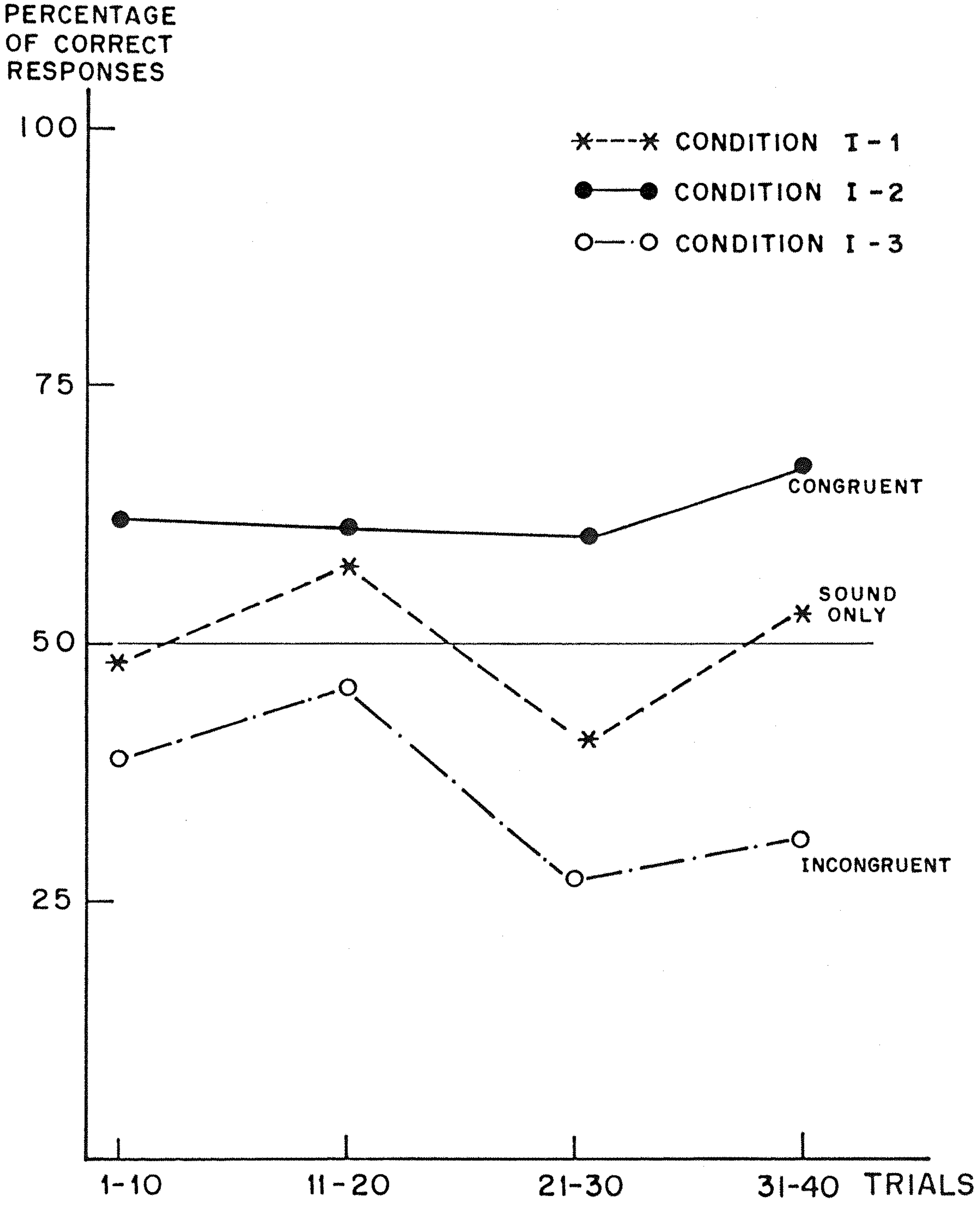
It can be observed in Fig. 2 that the total number of responses declined slightly through the conditions. The proportion of correct responses varied from aproximately half for the sound only group to 2/3 for the congruent group and to 1/3 in the incongruent group.

Fig. 3, Exp. I: Grouped data, total and correct audio-visual responses in blocks of 10 trials in the three experimental conditions: condition I-1, sound only; condition I-2, congruent and condition I-3, incongruent.



It can be observed in Fig. 3 that there was a decline block by block, especially in the congruent and incongruent condition, in the total number of responses as the session progressed and the number of trials that the subject received increased.

Fig. 4, Exp. I: Proportion of sound contingent eye movements ipsilateral to the auditory locus.



(iv)d) Further Statistical Analysis.

An analysis was also carried out to ascertain if there were significant differences between the proportion of the correct and incorrect number of responses (a) within the three experimental conditions, and (b) between the three experimental conditions.

Table 15, Exp. I: Average number of correct, incorrect and total number of responses, per experimental subject per condition.

Experimental conditions	N	Correct $\bar{x} \pm$ SD	Incorrect $\bar{x} \pm$ SD	TOTAL $\bar{x} \pm$ SD
Sound only	12	14 ± 3	14 ± 2	27 ± 5
Congruent	12	17 ± 4	10 ± 4	27 ± 7
Incongruent	12	9 ± 3	16 ± 5	25 ± 7
All Exp. I	36	13 ± 4	13 ± 5	26 ± 6

Notes :

Figures rounded up to the nearest whole number.

The t test for independent samples was applied to the data (a) within the 3 experimental conditions. No significant differences in the proportion of responses were found within the sound only group. The difference between the correct and incorrect number of responses was found to be significant beyond the 0.001 level for both the congruent and the incongruent conditions.

The variance (b) between conditions was found to be non significant considering the total number of responses, but significant for the correct number of responses ($p < 0.01$ $F_{(2-23)} = 15.5$).

The t test was applied for the correct number of responses between conditions. The results were found to be significant between all conditions. The sound only Vs congruent comparison was significant beyond 0.05; the congruent Vs. Incongruent conditions were significant beyond 0.001 and the comparison between sound only Vs Incongruent conditions was significant beyond the 0.01 level.

The experimental subjects taking part in this study had different characteristics, as has already been pointed out in Table 4. The experimenter thought it necessary to find out if the differences in the eye movements' patterns could be caused by the experimental subjects' characteristics, and not by the experimental conditions being manipulated. To this aim, the t test was carried out for the correct and total responses of the experimental subjects grouped according to their characteristics and an analysis of variance made for the drugs variable. The subjects were divided according to the following intervening variables (as described in Table 4), within each condition.

- sex:	male Vs female ,
- apgar:	low (<6) Vs high (>6) ,
- birth weight:	low (<2700grs) Vs high (>2700 grs)
- length of labour:	short (<6 hrs) Vs long (>6 hrs),
- birth order:	primipara Vs multipara ,
- drugs	given to mother before labour (no drugs Vs Pethidine & others Vs Epidural & others)

Table 16, Exp. I: <u>Average number of correct ($\bar{X}c$) and average number of total ($\bar{X}t$) responses per experimental subject, grouped according to their characteristics within each condition.</u>

Experimental Conditions		SEX		APGAR		BIRTH WEIGHT		LENGTH OF LABOUR		BIRTH ORDER		DRUGS		
		M	F	low	high	low	high	short	long	p	m	n	p	e
Sound only I-1 12 subjects	$\bar{X}t$	27	28	27	-*	27	-*	28	27	28	27	-*	27	28
	$\bar{X}c$	13	14	14	-*	14	-*	15	13	14	14	-*	14	14
Congruent I-2 12 subjects	$\bar{X}t$	26	27	25	28	27	-*	24	29	26	27	24	29	26
	$\bar{X}c$	17	16	16	17	17	-*	16	17	16	17	15	18	16
Incongruent I-3 12 subjects	$\bar{X}t$	29	20	23	30	25	-*	25	26	27	24	26	25	-*
	$\bar{X}c$	10	7	8	11	9	-*	9	9	10	8	8	9	-*

<u>Notes</u> :

-* no experimental subjects in this category.

BIRTH ORDER (p)rimipara
(m)ultipara

DRUGS (n)o drugs
(p)ethidine & others
(e)pidural & others

The results for the t tests and the analysis of variance for all the variables within all the experimental conditions for both the correct and the total number of responses proved to be non significant with only one exception. The male experimental subjects in the incongruent conditions gave significantly ($p<0.01$) more total responses than the females subjects in the same condition .

If all the experimental subjects had responded to each and all of the auditory stimuli there would have been a total of 1440 responses. However a total of 950 responses was actually given (a percentage of 66%).

Of the 950 responses given, 521 were to the left and 429 to the right. According to the binomial test, there was a significant ($p<0.001$) left directional bias.

(V) C O N C L U S I O N S.

(v)a) Conclusions on the analysis of individual data.

The results per individual subjects in condition I-1 (sound only, Table 5), showed that no experimental subjects produced significantly more eye movements in any one direction over the 40 trials. If we look at the blocks of trials, 2 subjects had significantly more eye movements in one direction, but in both cases no change was observed when the locus of the auditory stimulation was moved. The sound contingent eye movement remained as in the previous 10 trial block.

Referring to condition I-2 (congruent stimuli, Table 6) when we look at the blocks of trials, 6 experimental subjects out of 12 showed coordinated eye movements in at least one block of 10 trials, and 5 of these subjects' eye movements were ipsilateral with the locus of the auditory and visual stimuli. Over the 40 trials 4 experimental subjects showed significantly more eye movements in one direction and these were all ipsilateral with the sound and visual stimuli.

In the results for condition I-3 (incongruent visual and auditory stimuli, Table 7) looking at the 10 trials block, 7 subjects out of 12 showed significantly biased eye movements in at least one of the blocks, 6 of them being contralateral with the sound and towards the visual stimulus. Over the 40 trials, we find that 3 experimental subjects out of 12 showed significantly coordinated eye movements, all of them contralateral with the locus of the sound and towards the visual target.

As can be seen in Experiment I the 2 experimental conditions that elicited significantly more eye movements in any direction from some of the experimental subjects were those which incorporated a structured visual field. The presentation of an auditory stimulus on a blank white visual field was not effective in eliciting eye movement contingent with the sound different from chance.

The eye movements were analysed with respect to:

- latency with the sound,
- how far from the midline the eyes moved,
- length of time that the eyes stayed away from the midline.

The characteristics of the eye movements elicited by the 3 experimental conditions did not seem to differ.

Eighty nine percent of the experimental subjects responded to the first trial of the experimental session. However, the direction of their eye movements was at chance level (Table 8). Forty one percent of the oculomotor responses were ipsilateral with the locus of the sound.

When we look at the perseverance of the individual experimental subjects (Tables 9 and 10), we find that 8 experimental subjects out of 36 persevered in the first 10 trials, the highest proportion being in the incongruent condition. Three experimental subjects looked in the same direction as the first auditory stimulus they were given, while 5 looked away from their first auditory stimulus. Over the 40 trials, 11 experimental subjects out of 36 persevered and looked in the same direction as their first response. Again the highest proportion came from the incongruent condition group. Two of these subjects looked ipsilaterally with the locus of the sound, and 9 subjects contralaterally.

When perseverance is analysed considering the change in the locus of stimulation after each 10 trials (Tables 11 and 12), 14 experimental subjects out of 36 persevered. These 14 subjects looked away from the locus of the sound in slightly more than half of the blocks of trials.

(v)b) Conclusions on the Analysis of Grouped Data.

Looking at the grouped data (Tables 13 and 14), we can see that the responses for condition I-1 (sound only) were at chance level for the four 10 trial blocks as well as over the 40 trials. For condition I-2 (congruent stimuli), there were significantly more ($p<0.001$) eye movements towards the audio-visual stimuli for both the 4 blocks of 10 trials and over the 40 trials ($p<0.001$). For condition I-3 (incongruent stimuli), there were significantly more eye movements contralateral with the sound and towards the visual stimulus in the 40 trials and in 3 of the 4 blocks of 10 trials ($p<0.001$).

The evidence that emerged on some of the individual subjects in the analysis of grouped data is strengthened by the sum of responses per condition. Now there is strong evidence for spatial coordination in the conditions where a visual target was available. This coordination is present in the first block of 10 trials for both conditions with a visual stimulus. The coordinated eye movements take different forms in each of the experimental conditions. When auditory and visual stimuli share the same locus in space, the sound contingent eye movements are displayed towards the stimuli. When the auditory and visual stimuli are in opposite places in the visual field the sound contingent eye movements are displayed towards the visual stimulus and hence away from the auditory stimulus.

The total number of responses did not significantly vary between the 3 experimental conditions. However, the number of correct responses varied significantly between the three conditions (Table 15).

The individual experimental subjects' characteristics (Table 16) were not on the whole found responsible for the statistically different pattern of responses produced by the experimental subjects in the 3 experimental conditions.

A total of 950 responses was obtained out of a possible total of 1440, (66% response rate). When analysing the direction of these 950 responses it was found that there were 521 responses to the left and 429 to the right. This reflects a significant left directional bias ($p<0.001$).

In spite of the presence of a curtained window behind the left of the experimental subject's visual field, a photometer did not detect any different light intensity. As the overall results indicated a significant left directional bias, Experiment II was planned as a replication of Experiment I, however with the window blocked.

CHAPTER IV - EXPERIMENT II

(i) INTRODUCTION.

During the execution of Experiment I the experimenter gained the impression that the experimental subjects were looking in preference to the left of their visual field towards a window. In spite of the curtains being permanently drawn, there was a possibility that some light was filtering through.

A significant left directional bias was found in Experiment I when the total number of responses was scored. A photometer did not detect any difference in light intensity from the baby's position, but nevertheless, it was thought necessary to replicate Experiment I but with a smaller and different experimental sample.

Experiment II was carried out with the window covered with a black cloth. All other experimental conditions were kept the same.

The research objective of this experiment (as in Experiment I), was to evaluate the response of newborn experimental subjects to different conditions of audio-visual stimulation.

(ii) METHOD.

The experimental subjects received 4 blocks of 10 trials. A sound was given to the right (R) or left (L) of the subject. The sequence of sounds for each subject was either RLRL or LRLR. Half the subjects started with the R and the other half with the L. The auditory stimulation was kept invariable for all the experimental subjects and throughout the conditions. (See Table 3 for the experimental design).

- Condition I-1, or sound only in blocks group. The experimental subjects were given 40 trials while facing a blank visual field.

- Condition I-2, or congruent. The experimental subjects were given 40 trials during which the locus of the audio stimulus was congruent with the locus of the visual stimulus.

- Condition I-3, or incongruent. The experimental subjects were given 40 trials in which the locus of the audio stimulus was incongruent with the locus of the visual stimulus, i.e. the sound came from the opposite direction to that of the visual target.

(iii) E X P E R I M E N T A L   S U B J E C T S.

The experimental subjects were selected from babies at Southampton General Hospital Maternity Unit. They had to be normal, full term babies not more than 7 days old. (For a detailed description of the method and selection of the experimental subjects, see section (iv), Chapter II).

Twenty four experimental subjects took part in this experiment, 8 assigned to each experimental condition (namely I-1, I-2 and I-3). Their average age was 45 hours with a standard deviation of 26 hours and a range of 98 hours.

The characteristics of the 24 experimental subjects are described in Table 17.

Table 17, Exp.II: General caracteristics of the sample.

N	SEX		APGAR		BIRTH WEIGHT grs		BIRTH ORDER		LENGTH OF LABOUR hrs		DRUGS		
	M	F	x±SD	range	x±SD	range	x±SD	range	x±SD	range	no	1	2
24	8	16	8±1	3	3331 ±423	1530	2±1	3	7±1	15.5	6	15	3

Notes : Drugs

no = no drugs

1 = Pethidine, Entonox, Phenergon, Valium, Sparine etc.

2 = Epidural plus any other drugs

The subjects selected were of both sexes. More girls than boys were being born at the time the experiment took place and this bias is reflected in the sample. Even though the number of female subjects was higher than that of male subjects, the difference was not statistically significant. The healthy condition of the newborn experimental subjects was indicated by their 1 minute Apgar scores. The subjects' caracteristics seemed to be similar to those of normal babies delivered in hospital.

(iv) R E S U L T S .

iv)a) Analysis of Individual Data.

The figures in the following tables are the results of the analysis of the individual experimental subject's responses to Experiment II.

Tables 18, 19 and 20 represent the individual data for a general analysis in Exp. II. They are grouped according to the experimental condition given. Each box includes the percentage of correct responses out of the total responses given in a block of 10 trials. A correct response, as defined previously in the methodology chapter, is an eye movement in the same direction as the locus of the sound. The total column represents the equivalent percentage for the sum of all the trials; 4 blocks of 10 trials each. The figures in brackets in the total column represent the absolute total of correct and total responses per set of 4 blocks of 10 trials. To test the significance of the values the binomial test was applied.

Table 18, Exp. II: Individual audio-visual responses with visual stimulus absent and sound given in blocks of 10 trials (conditon I-1, sound only).

Trials / Exptal subjects	1-10	11-20	21-30	31-40	TOTAL
1	100% ** (7/7)	0% ** (0/7)	43% (3/7)	83% (5/6)	55% (15/27)
2	37% (3/8)	50% (2/4)	0% (0/3)	75% (3/4)	42% (8/19)
3	50% (4/8)	67% (4/6)	44% (4/9)	71% (5/7)	57% (17/30)
4	50% (2/4)	43% (3/7)	86% (6/7)	14% + (1/7)	48% (12/25)
5	50% (4/8)	50% (5/10)	75% (6/8)	60% (3/5)	58% (18/31)
6	50% (4/8)	83% (5/6)	67% (2/3)	100% (2/2)	68% (13/19)
7	50% (4/8)	60% (3/5)	75% (3/4)	75% (3/4)	62% (13/21)
8	50% (5/10)	43% (3/7)	17% (1/6)	71% (5/7)	47% (14/30)

*$p < 0.05$ **$p < 0.01$ + $0.05 < p < 0.10$ tendency

It can be observed from Table 18 that the group which was given condition I-1 (sound only in blocks) contains only 1 experimental subject (subject 1) showing significantly more eye movements in one direction. This subject looks towards the sound in the first block of 10 trials and keeps on looking in the same direction during the second block of 10 trials, in spite of the change in the locus of the sound. Over the 40 trials the experimental subjects' eye movements do not differ from those which could have been expected by chance.

Table 19, Exp. II: <u>Individual audio-visual responses, with visual stimulus congruent, and sound given in blocks of 10 trials. (condition I-2, congruent)</u>.

Trials / Exptal subjects	1-10	11-20	21-30	31-40	TOTAL
1	100% ** (8/8)	60% (6/10)	100% ** (8/8)	62% (5/8)	79% ** (27/34)
2	43% (3/7)	71% (5/7)	50% (2/4)	50% (3/6)	54% (13/24)
3	17% (1/6)	60% (3/5)	75% (3/4)	100% (2/2)	56% (9/17)
4	43% (3/7)	37% (3/8)	50% (3/6)	71% (5/7)	50% (14/28)
5	67% (6/9)	50% (4/8)	50% (4/8)	17% (1/6)	48% (15/31)
6	75% (3/4)	100% ** (7/7)	20% (1/5)	28% (2/7)	57% (13/23)
7	80% + (8/10)	100% ** (5/5)	87% * (7/8)	33% (3/9)	72% * (23/32)
8	62% (5/8)	67% (4/6)	50% (1/2)	33% (1/3)	58% (11/19)

*$p < 0.05$ **$p < 0.01$ + $0.05 < p < 0.10$ tendency

It can be observed in Table 19 that the group which was given a congruent audio-visual stimuli pattern (condition I-2) contains 2 experimental subjects (subjects 1 and 7) who show significantly more eye movements ipsilateral with the sound in two of the blocks of 10 trials. All the subjects responded at chance level in the last block (31-40). Two experimental subjects (subjects 1 and 7 again) over the 40 trials show significantly more ipsilateral eye movements with the sound and the visual stimuli.

Table 20, Exp. II: Individual audio-visual responses, with visual stimulus incongruent, and sound given in blocks of 10 trials. (condition I-3, incongruent).

Trials / Exptal subjects	1-10	11-20	21-30	31-40	TOTAL
1	30% (3/10)	80% (4/5)	0% (0/0)	0% (0/0)	47% (7/15)
2	33% (3/9)	17% (1/6)	100% (4/4)	20% (1/5)	37% (9/24)
3	22% + (2/9)	22% + (2/9)	50% (1/2)	100% (2/2)	32% (7/22)
4	0% * (0/6)	33% (1/3)	67% (2/3)	100% (1/1)	31% (4/13)
5	67% (4/6)	20% (1/5)	17% (1/6)	57% (4/7)	42% (10/24)
6	20% (1/5)	43% (3/7)	40% (2/5)	12% * (1/8)	28% * (7/25)
7	20% + (2/10)	0% ** (0/9)	17% (1/6)	0% * (0/5)	10% ** (3/30)
8	50% (2/4)	67% (2/3)	0% ** (0/9)	37% (3/8)	29% * (7/24)

*p < 0.05 **p < 0.01 + 0.05 < p < 0.10 tendency

In this last condition (incongruent audio-visual stimuli pattern, condition I-3) described in Table 20, there is one subject (subject 4) in the first block of 10 sounds who shows significantly more eye movements in one direction. The movements are contralateral with the sound. Only one subject in each block (subjects 7 and 8 respectively) shows significantly more eye movements away from the sound in the second and third blocks of 10 trials, and none towards the sound. Two experimental subjects (subjects 6 and 7) show significantly more contralateral eye movements in the last block of 10 trials (31-40). Three experimental subjects (subjects 6, 7 and 8) show significantly more eye movements in one direction over all the 40 trials, and they are all contralateral with the sound, i.e. towards the visual stimuli.

An analysis was also made of the information in relation to the direction of the experimental subjects' responses to the first trial and the direction of the first response. The results are shown in Table 21 where each box in the first trial row contains the total number of experimental subjects, over a total possible of 8 per condition, who responded in each direction to the first trial of the experimental session. The box indicates the direction of their eye movement in relation to the locus of the sound. Each box in the first response row describes the first responses of the experimental subjects, whenever that first response occurred. Each box indicates the direction of their eye movement in relation to the locus of the sound.

Table 21, Exp. II: Individual analysis of the eye movements' direction.

		towards the sound	Away from the sound	Total
Sound only condition I-1	*1 *2	4/8 5/8	2/8 3/8	6/8 8/8
Congruent condition I-2	*1 *2	5/8 6/8	2/8 2/8	7/8 8/8
Incongruent condition I-3	*1 *2	1/8 3/8	4/8 5/8	5/8 8/8
TOTAL EXPT. II	*1 *2	10/24 14/24	8/24 10/24	18/24 24/24

Notes :

*1 First trial

*2 First response

It can be seen from Table 21 that there are more responses to the first trial in the direction of the sound during the first 2 conditions (sound only in blocks and congruent stimuli). This is not the case for the incongruent group which contains 4 experimental subjects who look away from the sound and towards the visual stimuli out of the 5 who responded. The first response of the experimental subjects is slightly more oriented towards the locus of the sound for condition I-1 and I-2, though this is not statistically significant. More subjects look contralaterally to the locus of the sound for the incongruent condition.

Seventy five percent of the experimental subjects responded to the first trial of the experimental session, and 56% of those responses were ipsilateral with the sound.

iv)b) <u>Perseverance.</u>

Perseverance was studied with the aim of finding out whether the eye movements occurred in relation to the locus of the sound, or whether the sound acted rather as a trigger for the eye movement.

The results of Exp. II were re-analysed to find out if the experimental subjects showed in any way that they persevered in the direction of their eye movements.

To this end the responses of the experimental subjects were re-scored, taking as the correct response the eye movements in subsequent responses in the same direction as that of the first response (Table 22).

A response was also considered correct when the eye movement in subsequent responses was in the same direction as that of the first response after each change of auditory locus, i.e. following trial 1-11-21 and 31 (Table 24). The experimental subjects were considered to have shown perseverance if they had significantly more ($p < 0.05$) eye movements towards the direction of the trial, as described above.

Each box in Table 22 contains the number of experimental subjects who persevered or did not persevere, over a possible 8 per condition (subjects who persevered / 8).

Table 22, Experiment II: <u>Perseverance by individual experimental subjects.</u>

	Exptal subjects who persevered			Exptal subjects who did not persevere			Total who persevered	Total who did not per-severe
	sound only	congruent	incongruent	sound only	congruent	incongruent		
*1	1/8	2/8	2/8	7/8	6/8	6/8	5/24	19/24
*2	1/8	2/8	2/8	7/8	6/8	6/8	5/24	19/24

<u>Notes</u> :

*1 First ten trials taking as correct criteria the first response given by the experimental subject.

*2 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

Five experimental subjects persevered over the first 10 trials . One of these shows perseverance in the sound only condition, and two each in the congruent and incongruent conditions. The same number of experimental subjects show perseverance over the 40 trials as in the first trial.

The next table, Table 23, gives the direction in which the experimental subjects persevered in relation to the locus of the first sound. Each box gives the total number of experimental subjects, out of the total who persevered per condition, who persevered towards or away from the first sound (number of subjects who persevered towards or away from the first sound/total who persevered per condition).

Table 23, Exp. II: <u>Direction of the individual experimental subject's perseverance following their first responses.</u>

	Towards the locus of the first sound			Away from the locus of the first sound			TOTAL	
	sound only	congruent	incongruent	sound only	congruent	incongruent	toward first sound	away from first sound
*1	1/1	2/2	1/2	0/1	0/2	1/2	4/5	1/5
*2	1/1	2/2	1/2	0/1	0/2	1/2	4/5	1/5

<u>Notes</u> :

*1 First ten trials taking as correct criteria the first response given by the experimental subject.

*2 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

The experimental subjects who persevered in the first 10 trials and over all the 40 trials show that perseverance occurred only towards the direction of the sound for condition I-1 and I-2 (sound only and congruent group). The incongruent group (condition I-3) contains one experimental subject who shows ipsilateral perseverance and one who shows contralateral perseverance.

The next table, Table 24, gives the number of experimental subjects who persevered after each change in the locus of the auditory stimuli.

Table 24, Exp. II: Perseverance by individual experimental subjects after each change.

	Exptal subjects who persevered			Exptal subjects who did not persevere			Total who persevered	Total who did not persevere
	sound only	congruent	incongruent	sound only	congruent	incongruent		
*1	3/8	5/8	4/8	5/8	3/8	4/8	12/24	12/24

Notes :

*1 Over all 40 trials, taking as correct criteria the first response given by the experimental subject after each change, i.e. in trials 1-11-21 and 31.

When each change is taken into account, there are 12 experimental subjects who show perseverance.

Table 25 gives the results with respect to the direction of the eye movements of the 12 experimental subjects who persevered after each change in the locus of the audio stimulus. Each box contains the number of blocks of 10 trials during which the experimental subjects persevered either towards or away from the locus of the first sound. The box also contains the total of blocks of 10 trials where perseverance occurred after the change of locus of the auditory stimulus (number of blocks where perseverance occurred towards or away from the sound/number of blocks where perseverance occurred). The total number of blocks of trials showing perseverance was as follows: 12 in the sound only group (given by the 3 subjects who persevered, with 4 blocks each); 20 in the congruent group (given by the 5 subjects who persevered, with 4 blocks each); and 16 in the incongruent group (given by the 4 subjects who persevered with 4 blocks each).

Table 25, Exp. II: Direction of the eye movements of the individual experimental subjects who persevered after each change.

	Number of blocks of 10 trials towards the locus of the sound			Number of blocks of 10 trials away from the locus of the sound			TOTAL	
	sound only	congruent	incongruent	sound only	congruent	incongruent	toward	away
*1	6/12	11/20	4/16	6/12	9/20	10/16	21/48	25/48

Notes :

*1 Over all 40 trials, taking as correct criteria the first response given by the experimental subject after each change, i.e. in trials 1 - 11 - 21 and 31.

One experimental subject in the incongruent group did not give any responses in the last 2 blocks.

The experimental subjects who show perseverance after each change show a different pattern of response according to the condition they were given. The sound only group (condition I-1), looks half the time towards and the other half away from the locus of the sound. The congruent group (condition I-2), looks slightly though not significantly more towards the sound. The incongruent groups (condition I-3), looks significantly more away from the locus of the sound, i.e. towards the visual stimulus ($p < 0.05$).

(iv)c) Analysis of Grouped Data.

The next table, Table 26, analyses the results of the 24 experimental subjects as a group, summing up all the experimental subjects' responses. Each box shows (in brackets) the total number of sound contingent oculomotor responses ipsilateral and contralateral to the sound, in each of the three conditions.

Table 26, Exp. II: Grouped data, number of sound contingent oculomotor responses for the three experimental conditions: condition I-1, sound only; condition I-2, congruent and condition I-3, incongruent.

	Number of responses		
*1	Sound only	Congruent	Incongruent
Ipsilateral	(110) 54%	(125) ** 60%	(54) ** 30%
Contralateral	(92) 46%	(83) ** 40%	(123) ** 70%
TOTAL	(202)	(208)	(177)

** $p < 0.01$

Note :

*1 Eye movements with respect to the sound.

It can be seen in Table 26 that the congruent condition contains a significant majority of eye movements ipsilateral to the sound (and to the visual target; $p<0.01$). The eye movements during the incongruent condition are spatially contralateral to the sound (and towards the visual target; $p< 0.01$).

The proportion of eye movements toward and away from the sound are at chance level in the sound only condition.

The next table, Table 27, also analyses the results of the 24 experimental subjects as a group divided into 3 conditions. It gives the sum of all the experimental subjects' responses per condition, but divided in the four blocks of trials. Each box gives the percentage of correct responses over the total responses for all subjects, per block of 10 trials per condition. The total column represents the percentage of correct responses of the total of responses given for all the experimental subjects over all the trials. The figures in brackets represent the absolute number of correct responses over the absolute number of responses given in each block of 10 trials (number of correct responses/number of total responses). The figures in brackets in the total column give the absolute total number of correct responses over the total responses given for all the experimental subjects over all the trials (correct/total). The binomial test was applied in order to test the significance level of the results.

Table 27, Exp.II: Grouped data of audio-visual responses, by blocks of 10 trials in the three experimental conditions: condition I-1, visual stimuli absent sound only; condition I-2, visual stimuli congruent and condition I-3, visual stimuli incongruent .

TRIALS	1-10	11-20	21-30	31-40	TOTAL
Sound only condition I-1	54% (33/61)	48% (25/52)	53% (25/47)	64% * (27/42)	54% (110/202)
Congruent condition I-2	63% * (37/59)	66% ** (37/56)	64% * (29/45)	46% (22/48)	60% ** (125/208)
Incongruent condition I-3	29% ** (17/59)	30% ** (14/47)	31% ** (11/35)	33% * (12/36)	30% ** (54/177)
TOTAL	49% (87/179)	49% (76/155)	51% (65/127)	48% (61/126)	49% (289/587)

* p < 0.05) ** p < 0.01)

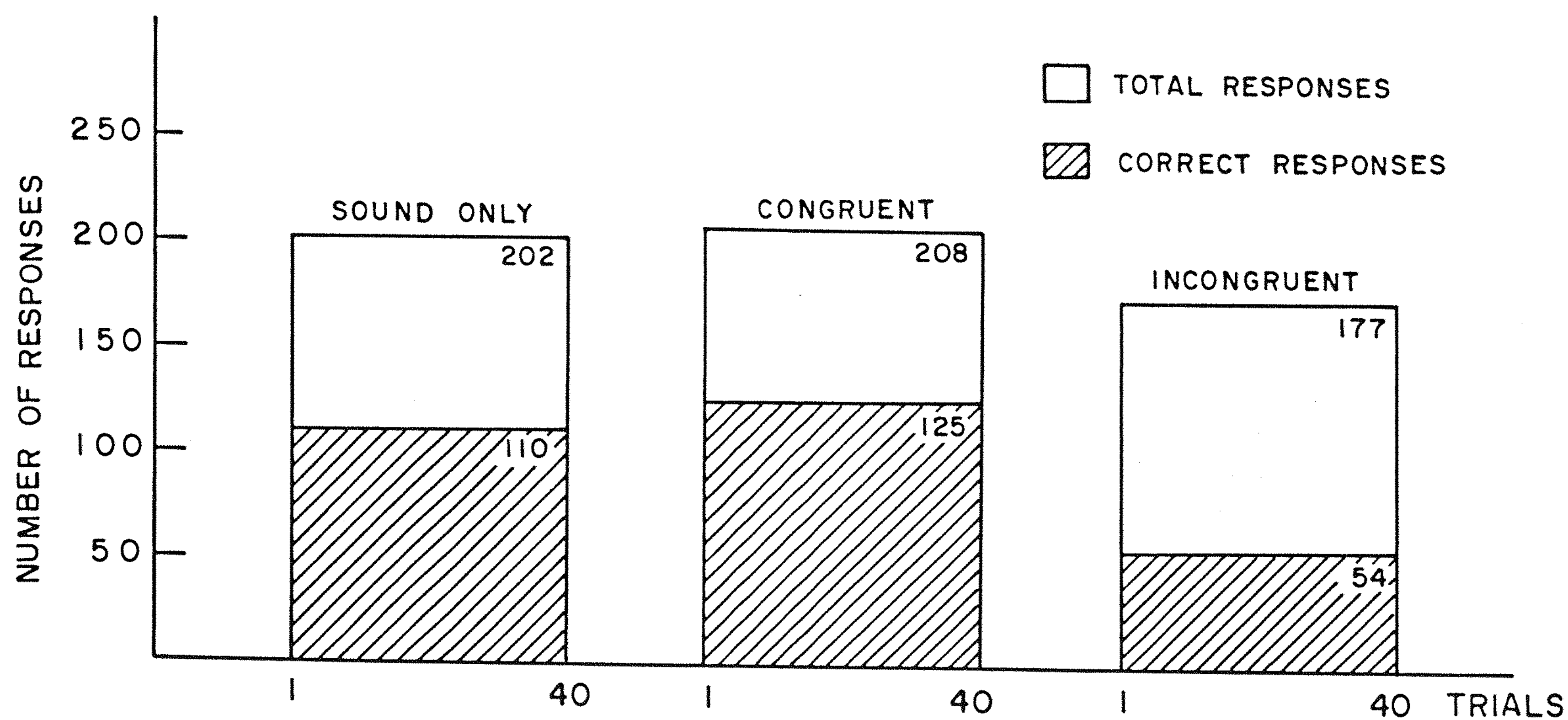
It can be seen from Table 27 that approximately half the responses to the sound for the sound only group are in one direction and the other half in the other. This pattern of responses is statistically equal to chance and is maintained throughout the first 3 blocks of trials. There are significantly more eye movements ipsilateral with the locus of the sound in the last block of 10 trials (31-40). Results at a chance level are found over the total of 40 trials. The congruent group of experimental subjects gave significantly more responses ipsilateral with the locus of the sound during the first 3 blocks of 10 trials. Responses are significantly ipsilateral with the sound over the 40 trials. The incongruent group gave eye movements significantly more contralaterally with the locus of the sound, i.e. towards the visual stimuli, through all the 4 blocks of 10 trials and also over the total of 40 trials.

Fig. 5 shows a graphic representation of Table 27. It takes the figures in brackets from the total column; the correct responses over the total responses.

Fig. 6 shows a graphic representation of the contents of Table 27. It takes the total responses out of the correct responses per block of 10 trials in each condition.

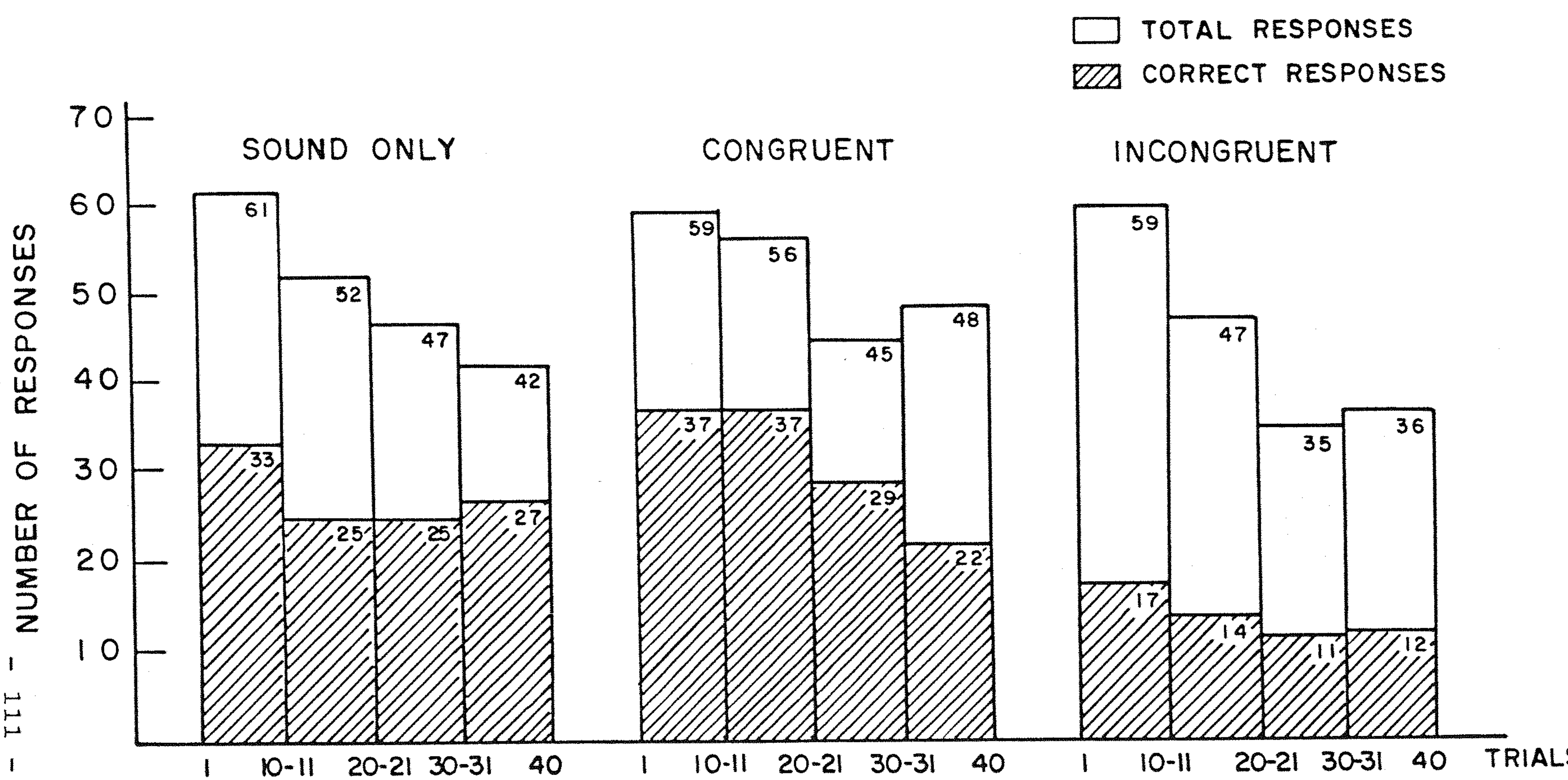
Fig. 7 shows a graphic representation of the contents of Table 27 as well, but in a proportional form.

Fig. 5, Exp. II: Grouped data, total and correct audio-visual responses for the three experimental conditions: condition I-1, sound only; condition I-2, congruent and condition I-3, incongruent.



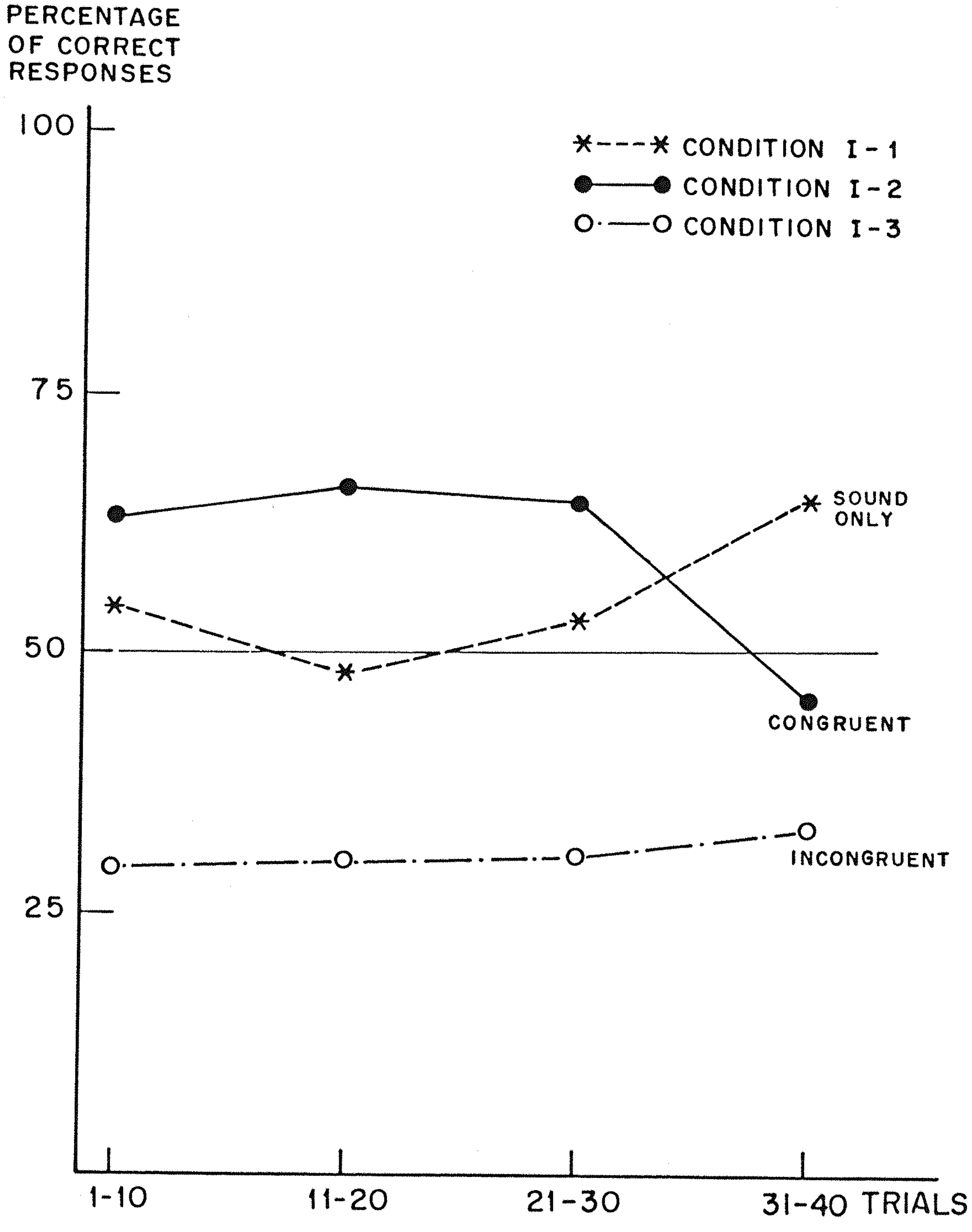
It can be observed in Fig.5 that the incongruent group contains less total responses than the previous two conditions. About half the responses of the sound only group are correct; the congruent group gives slightly more than half correct ones and the incongruent group only about a third correct responses out of the total.

Fig. 6, Exp. II: Grouped data, total and correct audio-visual responses in blocks of 10 trials in the three experimental conditions: condition I-1, sound only; condition I-2, congruent and condition I-3, incongruent.



It can be observed in Fig.6 that there is a decline in the total and correct number of responses for all conditions as the session goes on and the number of trials that the subjects have received increases.

Fig.7, Exp.II: Proportion of sound contingent eye movements ipsilateral to the auditory locus.



iv)d) Further Statistical Analysis.

An analysis was also carried out to ascertain if there were significant differences between the proportion of correct and incorrect responses (a) within the 3 experimental conditions and (b) between the 3 experimental conditions.

Table 28, Exp.II: Average number of correct, incorrect and total number of responses, per experimental subject per condition.

Experimental conditions	N	Correct $\bar{x} \pm SD$	Incorrect $\bar{x} \pm SD$	TOTAL $\bar{x} \pm SD$
Sound only	8	13 ± 3	12 ± 4	25 ± 5
Congruent	8	16 ± 6	10 ± 3	26 ± 6
Incongruent	8	7 ± 2	15 ± 6	22 ± 6
All Exp. II	8	12 ± 6	13 ± 5	24 ± 6

Notes :

Results rounded up to the nearest whole number

The t test for independent samples was applied to the data (a) within the 3 experimental conditions. No significant differences in the proportion of correct responses were found within the sound only group. The difference between the correct and incorrect number of responses was found to be significant beyond the 0.05 level for the congruent condition and significant beyond the 0.01 level for the incongruent condition

The variance (b) between conditions was found to be non-significant for the total number of responses, but significant for the correct number of responses ($p < 0.01$, $F(2-21) = 9.11$).

The t test was applied for the correct number of responses between conditions. The results were found to be non-significant for the sound only Vs congruent comparison. The results for the congruent Vs incongruent and incongruent Vs sound only comparisons were both significant ($p < 0.001$).

The experimental subjects taking part in this study had different characteristics (see table 17). The experimenter thought it necessary to ascertain if the differences in the eye movement patterns could be caused by the experimental subjects' characteristics and not by the experimental conditions being manipulated.

To this end a t test was carried out for the correct and total responses of the experimental subjects grouped according to their characteristics and an analysis of variance for the drugs category. The subjects were divided according to the following intervening variables (as described in Table 17), within each condition.

- sex: (male Vs female),
- apgar: (low <6 Vs high ≥6),
- birth weight: (low <2700 grs Vs high ≥2700 grs) ,
- length of labour: (short <6 hours Vs long ≥6 hours) ,
- birth order: (primipara Vs multipara),
- drugs given to the mother before labour (no drugs Vs Pethidine and others, (Vs Epidural and others)

Table 29, Exp II : Average number of correct ($\bar{X}c$) and average number of total responses ($\bar{X}t$) per experimental subject, grouped according to their characteristics within each condition.

Experimental Conditions		SEX		APGAR		BIRTH WEIGHT		LENGTH OF LABOUR		BIRTH ORDER		DRUGS		
		M	F	low	high	low	high	short	long	p	m	n	p	e
Sound only	$\bar{X}t$	26	25	-*	25	-*	25	24	26	28	23	19	30	26
8 subjects	$\bar{X}c$	15	12	-*	13	-*	13	14	12	15	11	7	13	14
I-1														
Congruent	$\bar{X}t$	28	26	-*	26	-*	26	30	20	22	28	30	22	-*
8 subjects	$\bar{X}c$	14	16	-*	16	-*	16	18	11	12	17	20	12	-*
I-2														
Incongruent	$\bar{X}t$	23	21	-*	22	-*	22	23	21	25	19	25	21	23
8 subjects	$\bar{X}c$	6	6	-*	7	-*	7	6	8	7	7	7	6	8
I-3														

Notes :

-* no experimental subjects in this category.

BIRTH ORDER (p)rimipara
(m)ultipara

DRUGS (n)o drugs
(p)ethidine & others
(e)pidural & others

The results for the t test and the analysis of variance for all the variables and within all the experimental conditions, for both the correct and the total number of responses, proved to be non-significant with only one exception. The experimental subjects in the congruent condition who were born after a short labour had significantly more ($p<0.02$) total responses than the subjects who were born after a long labour.

If all the experimental subjects had responded to each and all of the auditory stimuli there would have been a total of 960 responses. Actually a total of 587 responses was given (61%).

Of the 587 responses given, 298 were to the left and 289 to the right. The binomial test indicates that there was not a significant directional bias.

The left directional bias as detected in Exp. I, disappeared in the current experiment after putting a black cloth over the window. All other results were similar between the two experiments with this exception.

(v) C O N C L U S I O N S .

(v)a) Conclusions on the Analysis of Individual Data.

The results per individual subjects (condition I-1, sound only, Table 18), showed that no experimental subjects produced significantly more eye movements in any one direction over the 40 trials. There was only one experimental subject who had significantly more eye movements in one direction, but his sound contingent eye movements remained in the same direction after the change in the locus of auditory stimulation.

Three experimental subjects out of 8 in the congruent stimulus group (condition I-2, congruent stimulus, Table 19) showed coordinated eye movements in at least one block of 10 trials, and all of the subjects' eye movements were ipsilateral with the locus of the auditory and visual stimuli. Two experimental subjects showed significantly more eye movements over the 40 trials and all the responses were ipsilateral with the sound.

Four experimental subjects out of 12 showed significantly biased eye movements in at least one of the ten trial blocks in the results for condition I-3 (incongruent visual and auditory stimuli, Table 20). Their eye movements were all contralateral with the sound.

Three experimental subjects out of 8 were found to show significantly coordinated eye movements over the 40 trials, all of them contralateral with the locus of the sound and towards the visual stimulus.

The two conditions that elicited significantly more eye movements in any direction from some of the experimental subjects were those which incorporated a structured visual field. Experiment II in this sense provides the same results as Experiment I. It was not important where the visual target was placed or whether it was coincident or not with the locus of the auditory stimuli. However the analysis of individual results indicates that its presence was necessary to draw out coordinated eye movements. The characteristics of the experimental subjects' eye movements in the 3 experimental conditions seem to be similar.

Seventy five percent of the experimental subjects responded to the first trial of the experimental session (Table 21), but the direction of their eye movements was not different from chance (56% ipsilateral with the sound).

When we looked at the individual experimental subjects' perseverance (Tables 22 and 23), we found that 5 experimental subjects out of 24 persevered in the first 10 trials. Over the 40 trials 4 of these subjects looked in the same direction as that given in the first auditory stimulus, and 1 in the opposite direction. Twelve experimental subjects out of 24 were found to have persevered considering the change in the locus of stimulation after each 10 trials (Tables 24 and 25) . These 12 subjects looked away from the sound in slightly more than half of the blocks of trials.

(v)b) Conclusions on the Analysis of Grouped Data.

If we look at the grouped data for Experiment II (Tables 26 and 27) we can see that the total of responses for condition I-1 (sound only) was at chance level. However, the responses were significantly ipsilateral with the locus of auditory stimulation in the last block of 10 trials (31-40). Subjects receiving condition I-2 (congruent stimulus) displayed significantly more eye movements towards the audio-visual stimuli over the 40 trials in 3 of the 4 blocks of 10 trials ($p<0.01$). Those receiving condition I-3 (incongruent stimulus) displayed significantly more eye movements contralateral with the sound and towards the visual stimulus over the 40 trials in the 4 blocks of 10 trials ($p< 0.01$).

The evidence that emerged as significant in the analysis of individual data for some of the individual experimental subjects, is reinforced by the sum of responses per condition. There is strong evidence for spatial coordination in the experimental conditions where the visual target was available, as in Experiment I. This coordination is also present in the first 10 trials for both the congruent and incongruent conditions. Coordination for the condition with no visual information appears only in the last block of 10 trials.

The number of total responses did not significantly vary between the 3 experimental conditions. However, the number of correct responses between the 3 conditions varied significantly (Table 28).

The individual experimental subjects' characteristics (Table 29) were not on the whole found to be responsible for the statistically different patterns of responses produced by the experimental subjects to the different experimental conditions.

A total of 587 responses was obtained out of a possible total of 960 (61% response rate). When analysing the direction of these 587 responses, 298 were found to be to the left and 289 to the right, a non-significant directional bias.

CHAPTER V - EXPERIMENT III

Page

(i) I N T R O D U C T I O N.

In the previous two experiments only one visual target was present at anyone time and therefore it was not possible to determine whether the experimental subjects were looking at the target because it was the only one present irrespective of the locus of the audio stimulus, or because the experimental subjects assumed that the audio stimuli had to have the same locus as the visual targets.

Experiment III was designed to provide the experimental subjects with a permanently structured visual field, containing elements to support auditory memory but giving no cues as to the source of the sound.

Experiment III was designed as a complement to conditions I-2 and I-3 of the previous experiments.

(ii) M E T H O D .

In this experiment the structure of the visual field was kept constant. Identical visual targets placed in front of both concealed loudspeakers were presented simultaneously and continuously to all the experimental subjects. One target was placed to the right and the other to the left of the subject's visual field (see Table 3). The experimental variable manipulated was the pattern of audio stimulation, which was presented according to the following condition:

Condition III-1, or sound in blocks of 10 trials and two permanent visual stimuli. The experimental subjects were given 40 trials in which the audio stimulus came in 4 blocks of 10 trials each, with the audio stimulus pattern being RLRL and LRLR.

(iii) E X P E R I M E N T A L S U B J E C T S.

The experimental subjects were selected from babies at Southampton General Hospital Maternity Unit. They had to be normal full term babies, not older than 7 days old (for a detailed description of the method and selection of the experimental subjects, see Chapter II section (iv)).

Twelve experimental subjects took part in this study. All were assigned to condition III-1. Their average age was 37 hours, standard deviation 19 hours with a range of 60 hours.

The characteristics of the 12 experimental subjects are described in Table 30.

Table 30, Exp.III: General characteristics of the sample.

N	SEX		APGAR		BIRTH WEIGHT grs		BIRTH ORDER		LENGTH OF LABOUR hrs		DRUGS		
	M	F	$\bar{x}\pm SD$	range	$\bar{x}\pm SD$	range	$\bar{x}\pm SD$	range	$\bar{x}\pm SD$	range	no	1	2
12	7	5	8±1	4	3223 ±328	1130	2±1	2	7±6	24	2	7	3

Notes : Drugs

no = no drugs

1 = Pethidine, Entonox, Phenergon, Sparine, Valium, etc.

2 = Epidural plus any other drugs

The subjects selected were of both sexes. Their average 1 minute Apgar of 8 indicates that the babies were born in a healthy condition. Their birth weight, birth number, length of labour and type of drugs given to the mothers during birth seemed to be similar to other normal hospital deliveries.

(iv) R E S U L T S .

(iv)a) Analysis of Individual Data.

The following tables are the result of the analysis of the individual experimental subjects' responses to Experiment III.

Table 31 represents the individual data from a general analysis of the results of this experiment. Each box includes the percentage of correct responses out of the total responses given in a block of ten trials. The total column represents the percentage of total correct responses out of the total responses over the four blocks of 10 trials each. The figure in brackets represents the absolute number of correct over total responses per ten trial block. The figure in brackets in the total column represents the absolute total of correct and total responses per set of four blocks of ten trials. The binomial test was applied to test the significance of the values .

Table 31, Exp.III: Individual audio-visual responses when two permanent visual stimuli were present, and the sound given in blocks of 10 trials (condition III-1).

Trials / Exptal subjects	1-10	11-20	21-30	31-40	TOTAL
1	88% * (7/8)	33% (2/6)	75% (6/8)	33% (2/6)	61% (17/28)
2	30% (3/10)	56% (5/9)	78% + (7/9)	70% (7/10)	58% (22/38)
3	80% + (8/10)	50% (4/8)	20% + (2/10)	80% + (8/10)	58% (22/38)
4	80% (4/5)	0% (0/3)	100% * (5/5)	0% * (0/5)	50% (9/18)
5	63% (5/8)	56% (5/9)	75% (6/8)	29% (2/7)	56% (18/32)
6	60% (3/5)	44% (4/9)	60% (3/5)	63% (5/8)	56% (15/27)
7	89% * (8/9)	13% * (1/8)	100% * (8/8)	30% (3/10)	57% (20/35)
8	100% ** (7/7)	60% (3/5)	38% (3/8)	0% (0/3)	57% (13/23)
9	40% (4/10)	50% (2/4)	100% ** (7/7)	14% + (1/7)	50% (14/28)
10	90% * (9/10)	60% (3/5)	60% (6/10)	100% (4/4)	76% ** (22/29)
11	0% * (0/6)	100% ** (9/9)	25% (2/8)	100% * (6/6)	59% (17/29)
12	89% * (8/9)	30% (3/10)	44% (4/9)	25% (1/4)	50% (16/32)

*$p < 0.05$ **$p < 0.01$ +$0.05 < p < 0.10$ (tendency)

It can be observed in Table 31 that 6 experimental subjects (subjects 1, 7, 8, 10, 11 and 12) show significantly more eye movements to one side or other of the structured visual field during the first 10 trials (1-10). Five of the subjects show movements ipsilateral to the locus of the sound and one shows movements contralateral to the sound. One experimental subject (subject 11) shows significantly more ipsilateral eye movements in the second block of 10 trials (11-20), and another (subject 7) shows significantly more contralateral eye movements. Three subjects (subjects 4, 7 and 9) show significantly more ipsilateral eye movements in the third block of 10 trials (21-30). Two experimental subjects show significantly more eye movements towards one locus of the visual field in the last block of ten trials (31-40); one (subject 11) ipsilateral to and the other (subject 4) contralateral to the locus of the sound. Only one subject (subject 10) shows significantly more eye movements ipsilateral to the sound over the 40 trials. All other experimental subjects' eye movements are similar to those which could have been expected by chance.

An analysis was carried out of the direction of the experimental subjects' responses to the first trial and also of the direction of the subjects' first response. The results are shown in Table 32. Each box of the first trial row of the table contains the total number of experimental subjects over a total possible of 12 for the experimental group, who responded to the first trial of the experimental session. It indicates the direction of their eye movement in relation to the sound. Each box of the first response row of the table contains the first response of the experimental subjects whenever that first response occurred. Each box indicates the direction of their eye movements in relation to the locus of the sound.

Table 32, Exp.III: <u>Individual analysis of the eye movements direction.</u>

	Towards the sound	Away from the sound	Total
First trial	6/12	5/12	11/12
First response	6/12	6/12	12/12

It can be seen in Table 32 that there is no significant deviation from chance of the 11 first responses given by the 12 experimental subjects who responded to the first trial. Neither is there a significant deviation from chance of the first responses of the 12 subjects. Subjects responded equally towards and away from the audio stimulus they were given. Ninety two percent of the subjects responded to the first trial of the experimental session.

(v)b) Perseverance.

The perseverance of the subjects' eye movements was studied with the aim of finding out whether there was a relation between the direction of the eye movements and the locus of the sound, or if the sound acted rather as a trigger for the eye movement.

The results of Experiment III were re-analysed to ascertain whether the experimental subjects showed in any way that they persevered in the direction of their eye movements. Perseverance was found if the subjects repeated the direction of the eye movement of their first response (Table 33). It also was found if they repeated the direction of the eye movement of the first response after each change in the locus of the auditory stimuli (i.e. that of trials 1-11-21 and 31; Table 35).

The experimental subjects were considered to have shown perseverance if they had significantly more ($p<0.05$) eye movements in the direction mentioned above. Each box of Table 33 gives the number of experimental subjects who did or did not persevere out of a possible total of 12 subjects (subjects who persevered/12).

Table 33, Exp. III: <u>Perseverance by individual experimental subject</u>

	Total of exptal subjects who persevered	Total of exptal subjects who did not persevere
*1	7/12	5/12
*2	6/12	6/12

<u>Notes</u> :

*1 First ten trials taking as correct criteria the first response given by the experimental subject.

*2 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

Seven experimental subjects persevered in their eye movements in the first 10 trials (1-10), repeating the direction of their first response. Six of these repeated the same direction over the 40 trials.

The next table, Table 34, gives the direction in which the experimental subjects persevered in their responses in relation to the locus of the first auditory stimulus. Each box gives the total number of experimental subjects who persevered towards or away from the first sound out of the total who persevered in the group.

Table 34, Exp.III: Direction of the individual subjects' perseverance, following the first response.

	Towards the locus of the first sound	Away from the locus of the first sound
*1	4/12	3/12
*2	2/12	4/12

Notes :

*1 First ten trials taking as correct criteria the first response given by the experimental subject.

*2 Over all 40 trials, taking as correct criteria the first response given by the experimental subject.

The experimental subjects who persevered both during the first 10 trials and over all the 40 trials show that this perseverance occured in both directions, ipsilateral and contralateral with the first sound.

The next table, Table 35, gives the number of experimental subjects who persevered in their responses, after each change in the locus of the auditory stimuli.

Table 35, Exp.III: Perseverance in responses by individual experimental subjects after each change.

	Total of exptal subjects who persevered	Total of exptal subjects who did not persevere
*1	8/12	4/12

Note :

*1 Over all 40 trials, taking as correct criteria the first response given by the experimental subject, after each change i.e. in trials 1-11-21-31.

The results of each individual subject were scored, taking into account each change in direction of auditory stimulus. Responses 1-11-21 and 31 were considered as the correct direction for a response. Eight out of twelve experimental subjects show significantly more eye movements in the same direction as the response after each change.

An analysis was made of the results for the eight experimental subjects who persevered in the direction of their eye movements following each change in the locus of the auditory stimulation. This analysis reveals that of the 32 blocks (given by the 8 experimental subjects who persevered with 4 blocks each) within which the subjects showed perseverance, 15 blocks of trials showed perseverance towards the locus of the sound and 17 away. In other words, the response exhibited was distributed equally towards and away from the auditory stimulus.

(iv)c) Analysis of the Grouped Data

The next table, Table 36, analyses the results of the 12 experimental subjects as a group summing up all the experimental subjects' responses. Each box shows the total number of sound contingent oculomotor responses ipsilateral and contralateral to the sound, and the corresponding percentage in brackets.

Table 36, Exp.III: Grouped data, number of sound contingent oculomotor responses with 2 permanent visual stimuli present, one congruent with the sound (condition III-1).

*1	Number of responses
Ipsilateral	205 ** (57%)
Contralateral	152 ** (43%)
TOTAL	357

** $p < 0.01$

Note :

*1 Eye movements with respect to the sound.

As can be seen in Table 36, 205 eye movements are displayed towards the sound and only 152 away in spite of the presence of two visual stimuli.

Table 37 also analyses the results of the 12 experimental subjects as a group, but divided into the 4 blocks of trials. Each box gives the percentage of correct responses for all subjects per block of 10 trials, out of the total responses given in this block. The total column represents the percentage of correct responses given by all subjects for all the trials, over the total responses given by all the experimental subjects over all the trials. The figures in brackets represent the absolute number of correct responses given by all subjects over the absolute number of responses given by all subjects in each block of 10 trials (correct responses/total responses). The figures in brackets in the total column give the absolute total number of correct responses for all subjects over the total responses given for all the experimental subjects over all the trials (correct/total). The binomial test was used to test the significance level of the data.

Table 37, Exp. III: <u>Grouped data of audio-visual responses by blocks of 10 trials and 2 permanent visual stimuli present, one congruent with the sound. (condition III-1).</u>

Trials	1-10	11-20	21-30	31-40	TOTAL
12 Exptal subjects	68% ** (66/97)	48% (41/85)	62% * (59/95)	49% (39/80)	57% ** (205/357)

*p < 0.05 **p < 0.01

As can be observed in Table 37, the experimental subjects show significantly more ipsilateral eye movements during the first (1-10) and third (21-30) blocks of 10 trials. The eye movements are also significantly biased towards the sound over the total of 40 trials.

Fig. 8 gives a graphic representation of the total column in Table 37. It shows the total and correct number of responses for the 40 trials.

Fig. 9 gives a graphic representation of Table 37, taking the figures in brackets of the 4 blocks of 10 trial each (correct and total responses).

Fig. 10 also gives a graphic representation of the data of Table 37, but in a proportional form.

Fig. 8, Exp. III: Grouped data, total and correct audio-visual responses for the 40 trials where 2 permanent visual stimuli were present (condition III-1).

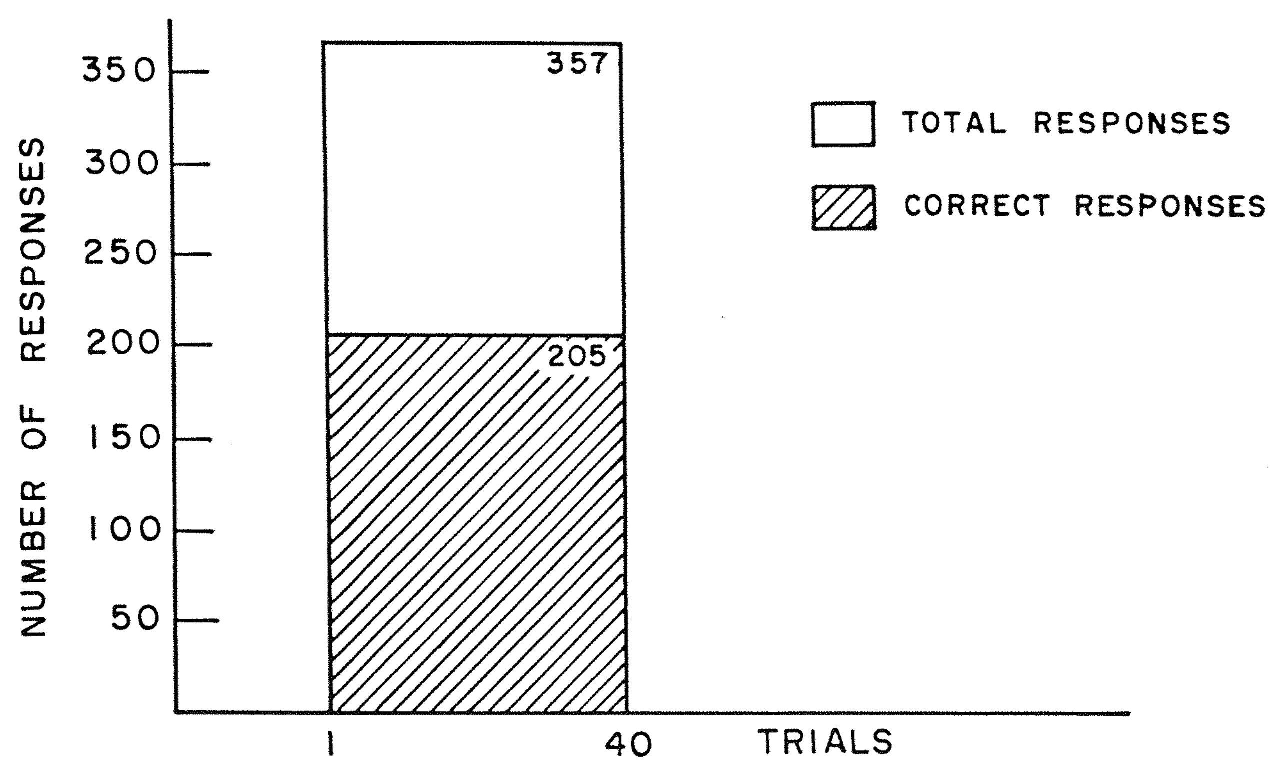
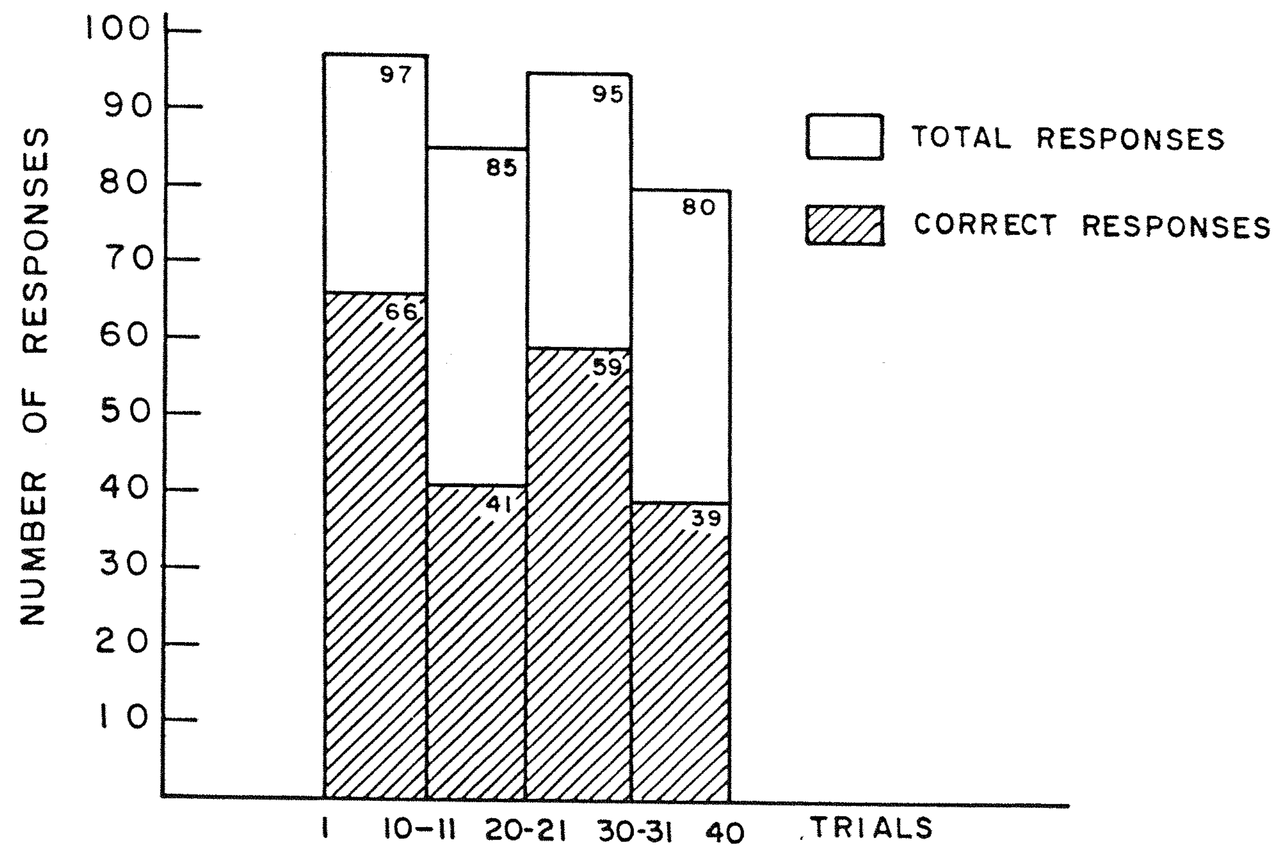
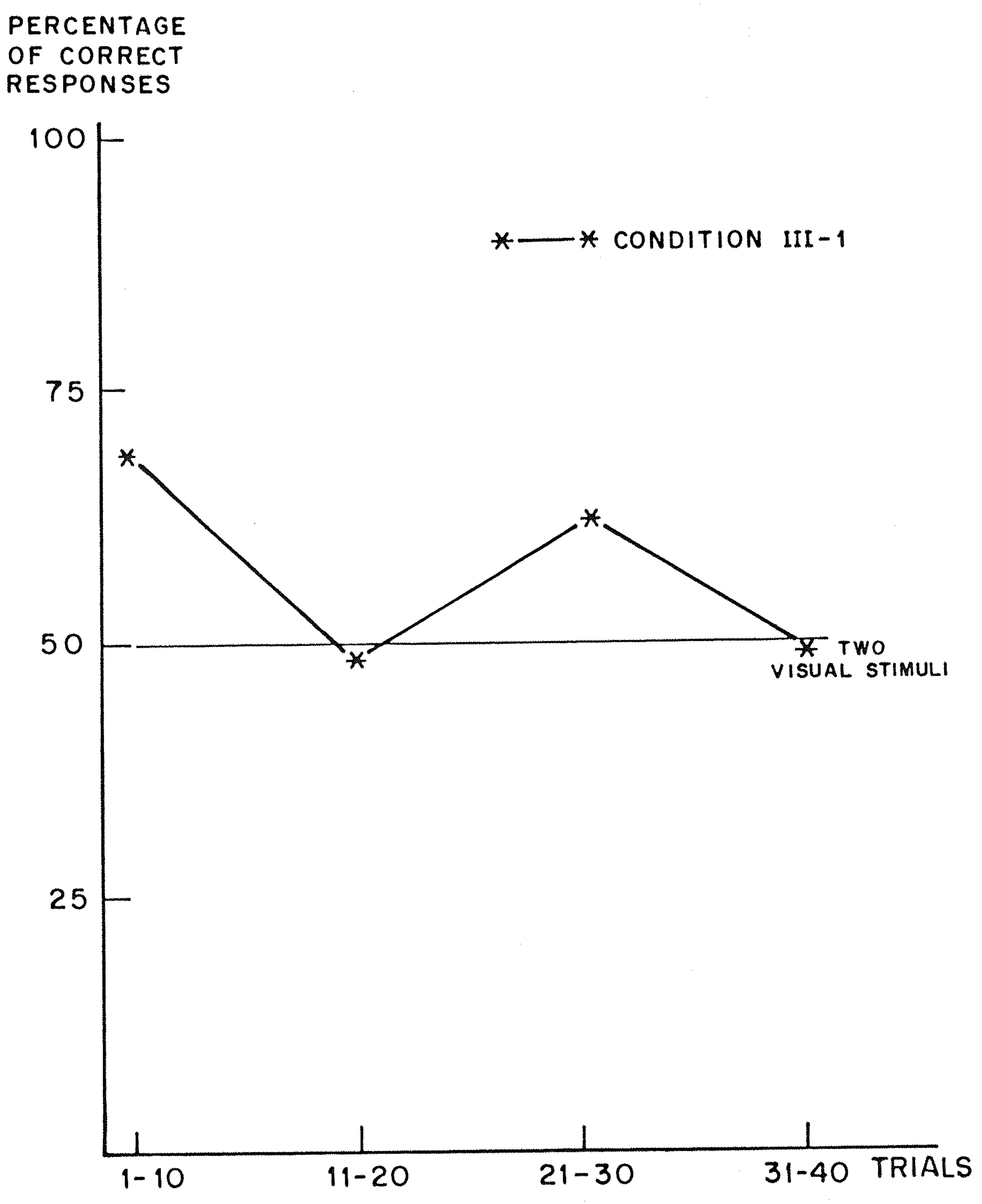


Fig. 9, Exp. III: Grouped data of audio-visual responses by blocks of 10 trials and 2 permanent visual stimuli present (condition III-1).



It can be observed in Fig. 9 that there is a higher total number of responses and also a higher proportion of correct responses in trials 1-10 and 21-30 than in the second and fourth blocks of 10 trials.

Fig.10, Exp.III: Proportion of sound contingent eye movements ipsilateral to the auditory locus.



(iv)d) Further Statical Analysis.

An analysis was carried out to ascertain whether there were significant differences between the proportion of correct and incorrect numbers of responses within the experimental condition.

Table 38, Exp.III: Average number of correct, incorrect and total number of responses per experimental subject.

	N	Correct x ± SD	Incorrect x ± SD	TOTAL x ± SD
Sound in blocks, two permanent visual stimuli	12	17 ± 4	13 ± 3	30 ± 6

Note :

Figures rounded up to the nearest whole number.

The t test for independent samples was applied to the data. The difference between the correct and incorrect number of responses was found to be significant beyond the 0.01 level.

The experimental subjects taking part in this study possessed different characteristics as has already been pointed out in Table 30. The experimenter thought it necessary to find out if the differences in the eye movements' patterns could be caused by the experimental subjects' characteristics and not by the experimental conditions being manipulated. To this aim, the t test was carried out for the correct and total responses of the experimental subjects grouped according to their characteristics and an analysis of variance made for the drugs variable. The subjects were divided according to the following intervening variables (as described in Table 28), within the conditions.

- sex	(male Vs female),
- apgar	(low <6 Vs high ≥ 6),
- birth weight	(low <2700 grs Vs high ≥ 2700grs)
- birth order	(primipara Vs multipara),
- length of labour	(short <6 hours Vs long ≥ 6 hours),
- drugs	given to the mother before labour (no drugs Vs Pethidine and others Vs Epidural and others).

Table 39, Exp.III: Average number of correct ($\bar{X}c$) and average number of total ($\bar{X}t$) responses per experimental subject, grouped according to their characteristics within the condition.

		SEX		APGAR		BIRTH WEIGHT		LENGTH OF LABOUR		BIRTH ORDER		DRUGS		
		M	F	low	high	low	high	short	long	p	m	n	p	e
12 subjects	$\bar{X}t$	31	28	30	28	-*	30	34	28	27	31	28	30	30
	$\bar{X}c$	17	17	17	17	-*	17	19	17	15	18	15	18	16

Notes :

-* no experimental subjects in this category.

BIRTH ORDER (p)rimipara
(m)ultipara

DRUGS (n)o drugs
(p)ethidine and others
(e)pidural and others

The results for the t test and the analysis of variance for all the variables within the experimental condition proved to be non-significant.

If all the experimental subjects had responded to each and all of the auditory stimuli there would have been a total of 480 responses. However, a total of 357 responses was actually given (74%).

Of the 357 responses given, 163 were to the left and 194 to the right. In spite of a difference of 31 more responses to the right a significant directional bias was not found when the binomial test was applied.

(V) C O N C L U S I O N S .

(v)a) Conclusions on the Analysis of Individual Data.

In this experiment all the experimental subjects were given the same experimental condition of 2 permanent visual stimuli presented simultaneously with the auditory stimulation. Eight experimental subjects out of 12 showed significantly more eye movements in one direction in at least one of the blocks of trials (blocks of 10 trials, Table 30). The eye movements were in the same direction as the auditory stimulus in 10 out of 13 of those blocks. Only one experimental subject showed significant coordination with eye movements ipsilateral to the locus of the sound over the 40 trials.

Ninety two percent of the experimental subjects responded to the first trial of the experimental session (Table 32), but the direction of their first eye movement was not different from chance (55 % ipsilateral with the locus of the sound).

When we look at the perseverance of the individual experimental subjects (Tables 33 and 34), we find that 7 experimental subjects out of 12 persevered in the first 10 trials. Four of these looked towards the locus of the first auditory stimulus given and 3 away. Six experimental subjects persevered over the 40 trials; 2 kept looking in the same direction as the first auditory stimulus they were given and 4 away .

Eight out of 12 experimental subjects are seen to persevere when the data is analysed taking into account the change in locus of stimulation after each 10 trials (Table 35). These 8 subjects looked away from the locus of the sound in slightly more than half of the blocks of trials.

(v)b) Conclusions on the Analysis of Grouped Data.

If we look at the grouped data for Experiment III (Tables 36 and 37), we can see that there was a significant number of coordinated eye movements in the direction ipsilateral with the sound during the first (1-10) and third (21-30) blocks of 10 trials. Table 37 shows that significantly more eye movements ($p<0.01$) were displayed in the same direction as the locus of the auditory stimulus (overall results, summing the 40 trials for all the experimental subjects).

The coordination that was evident in only one experimental subject in the individual analysis is strengthened by the sum of the group responses and becomes highly significant.

When two visual targets were permanently present the sound contingent eye movement was directed towards only one of them; the one that was coincident with the locus of the auditory stimulus.

The individual experimental subjects' characteristics (Table 39) were not found to have any incidence on the patterns of responses of the experimental subjects.

A total of 357 responses was obtained out of a possible total of 480 (74 % response rate).

Of these 357 responses, 163 were to the left and 194 to the right, a non-significant directional bias.

CHAPTER VI - EXPERIMENT IV

Page

(i) INTRODUCTION.

Auditory stimuli were given in blocks of 10 trials in experiments I, II and III. Evidence of auditory-visual coordination was found in those experimental conditions whose visual field was structured and at certain points of the experimental sessions when the source of the sound had maintained its locus during several trials.

Experiment IV was designed to measure the development of the infants' responses under different experimental conditions.

Auditory stimuli were presented randomly to the right or left of the baby's head. The pattern of audio stimulation was repeated for all experimental subjects. However, the visual field was presented in two different modalities; one structured with two cards permanently present (ST) and the other blank (BL).

The oculomotor responses were recorded for experimental subjects whose age ranged from newborn to 6 months.

(ii) M E T H O D.

All the experimental subjects were presented with the same type of stimuli pattern (see Table 3). To that effect, 40 random sequences of audio-stimuli were worked out following a Gellerman Table.

A sound was given randomly from either of two fixed points to the right or left of the visual field. Each schedule of auditory stimuli contained a total of 40 trials, with roughly the same number of sounds coming from the left and right. The experimental subjects were allocated randomly to one of the audio sequences.

The experimental variable that was manipulated was the structure of the visual field, according to the following conditions:

- Condition IV-1, ST or sound at random and 2 permanent visual stimuli. The experimental subject was given 20 sounds randomly while facing 2 permanent visual targets, one placed at the right and the other at the left of the subject's perceptive field (ST).

- Condition IV-2, BL or sound only random. The experimental subject was given 20 sounds randomly while facing a blank perceptive field (BL).

All the subjects were given conditions (IV-1, ST) and (IV-2, BL) separated by a 40 seconds interval. Half the subjects were given condition (IV-1, ST) first followed by condition (IV-2, BL). The remaining subjects were given the conditions in reverse order.

(iii) EXPERIMENTAL SUBJECTS.

This experiment included experimental subjects whose age ranged from newborn to 6 months. The newborn experimental subjects (group 1) were selected from babies at Southampton General Hospital Maternity Unit. They had to be normal full term babies not older than 7 days. The older infants were selected by their age from a volunteer bank registered in the Department of Psychology of Southampton University. (For a detailed description of the method and selection of the experimental subjects, see section (iv) Chapter II).

Table 40 describes the characteristics of the 40 experimental subjects who took part in this experiment. The subjects were allocated to different groups according to their age.

Table 40, Exp. IV: General characteristics of the sample.

Group	N	AGE		SEX		APGAR		BIRTH WEIGHT gr		BIRTH ORDER		LENGTH OF LABOUR hrs		DRUGS		
		x̄±SD	rg	M	F	x̄±SD	rg	x̄±SD	rg	x̄±SD	rg	x̄±SD	range	n	1	2
1	8	30±18 hr	50 hr	2	6	7±2	6	3546 ±205	1770	2±1	3	7±5	10	2	5	1
2	8	7±2 wk	4 wk	5	3	–	–	3588 ±384	1264	1.5 ±1	2	–	–	0	4	4
3	8	13±1 wk	3 wk	4	4	–	–	3584 ±402	1103	1±1	2	–	–	1	2	5
4	8	19 wk ±1.5	4 wk	6	2	–	–	3365 ±551	1530	1.5 ±0.5	1	–	–	1	3	4
5	8	27±3 wk	6 wk	5	3	–	–	3440 ±562	1760	1 ±0.3	1	–	–	1	3	4

Notes :

rg = range

Drugs
n = no drugs
1 = Entonox, Pethidine, Phenergon, Valium, Sparine, etc.
2 = Epidural plus any other (Pethidine, Phenergon, Valium, Sparine, etc.).

– In this experiment, the information regarding groups 2,3,4 and 5 was obtained from the mothers. As most of them were not aware of the Apgar test administered to their babies and did not remember with any accuracy their length of labour or their Apgar score, this data was not included in the table. The mothers' information with reference to the drugs administered during labour has to be taken with limited confidence as it was not checked with the Hospital records.

The only group of randomly selected subjects described in Table 40 was group 1, the newborn subjects. This group's characteristics seem to be similar to the ones generally observed in babies delivered in hospital. The older experimental subjects belonging to groups 2,3,4 and 5 as mentioned in the subjects' section, were selected by age. Whenever possible a balance of the sexes was made for all groups.

The older subjects came from a volunteer bank and can be expected to have some special characteristics different from those of the newborn subjects contacted in hospital. The general characteristics are observed in Table 40. The first to be mentioned is birth order. There are many more first born babies than the number found in the newborn random sample. The second special characteristic is the kind of drugs given to the mothers during labour. Approximately half of the mothers reported to have received Epidural plus other drugs.

(iv) R E S U L T S.

(iv)a) Analysis of the Individual Data.

The figures in the following tables are the results of the analysis of the individual experimental subjects' responses in Experiment IV.

Tables 41, 42, 43, 44 and 45 represent the individual data for a general analysis. The subjects were grouped according to their age and the experimental conditions they were given.

Each box in the following table includes the percentage of correct responses out of the total responses given in a block of 10 trials. The total colummn represents the equivalent percentage for all the correct and total responses for all the trials, i.e. per 4 blocks of 10 trials each. The figures in brackets represent the absolute number of correct over total responses per 10 trial block (correct responses/total responses). The figures in brackets in the total column represent the absolute total of correct and total responses per set of 4 blocks of 10 trials. The binomial test was applied to test the significance of the values.

The first 4 experimental subjects to be described in each of the next 5 tables (Tables 41 to 45), were given 20 trials facing a structured visual field, followed by 20 trials facing a blank visual field. The remaining 4 subjects described in the table (5 to 8), were presented with a blank visual field first, followed by a structured visual field.

The next table, Table 41, describes the results for group 1, the newborn experimental group.

Table 41, Exp. IV: Individual audio-visual responses for group 1 (newborn subjects), when the visual stimuli were permanently present (condition IV-1, ST), and absent (condition IV-2, BL). The audio stimuli were given in a random fashion.

Trials Exptal. subjects	1-10	11-20	21-30	31-40	TOTAL
	STRUCTURED		BLANK		
1	67% (4/6)	60% (3/5)	67% (4/6)	67% (2/3)	65% (13/20)
2	50% (3/6)	71% (5/7)	17% (1/6)	25% (2/8)	41% (11/27)
3	60% (3/5)	44% (4/9)	44% (4/9)	57% (4/7)	50% (15/30)
4	25% (2/8)	67% (2/3)	56% (5/9)	20% + (2/10)	37% (11/30)
	BLANK		STRUCTURED		
5	56% (5/9)	100% * (6/6)	50% (4/8)	29% (2/7)	57% (17/30)
6	50% (5/10)	40% (4/10)	57% (4/7)	37% (3/8)	46% (16/35)
7	50% (3/6)	44% (4/9)	44% (4/9)	80% (4/5)	52% (15/29)
8	40% (4/10)	33% (3/9)	50% (5/10)	57% (4/7)	44% (16/36)

*$p < 0.05$ **$p < 0.01$ +$0.05 < p < 0.10$ (tendency)

It can be observed in Table 41 that only one subject in this newborn sample (subject 5, block 11-20) shows significantly more eye movements ipsilateral to the audio stimuli. This subject was presented with a blank visual field in the first 20 trials. None of the newborn subjects' eye movements were significantly different from that to be expected from chance over the 40 trials.

The next table, Table 42, describes the results for group 2, the 7 weeks old (on average) experimental subjects.

Table 42, Exp. IV: Individual audio-visual responses for group 2 (average 7 weeks old subjects), when the visual stimuli were permanently present (condition IV-1, ST) and absent (condition IV-2, BL). The audio stimuli were given in a random fashion.

Trials / Exptal. subjects	1-10	11-20	21-30	31-40	TOTAL
	STRUCTURED		BLANK		
1	50% (2/4)	25% (1/4)	25% (1/4)	60% (3/5)	41% (7/17)
2	60% (3/5)	60% (3/5)	50% (4/8)	60% (3/5)	57% (13/23)
3	17% (1/6)	43% (3/7)	33% (1/3)	50% (1/2)	33% (6/18)
4	60% (6/10)	56% (5/9)	71% (5/7)	43% + (3/7)	58% (19/33)
	BLANK		STRUCTURED		
5	57% (4/7)	40% (2/5)	50% (3/6)	50% (3/6)	50% (12/24)
6	57% (4/7)	50% (1/2)	71% (5/7)	80% (4/5)	67% (14/21)
7	100% (3/3)	75% (3/4)	50% (4/8)	57% (4/7)	64% (14/22)
8	33% (2/6)	75% (3/4)	50% (4/8)	50% (1/2)	50% (10/20)

*$p < 0.05$ **$p < 0.01$ +$0.05 < p < 0.10$ (tendency)

It can be observed in Table 42 that all 7 weeks old (on average) subjects respond equally towards and away from the source of the sound in the 4 blocks and over the 40 trials.

The next table, Table 43, describes the results for group 3, the 13 weeks old (on average) experimental subjects.

Table 43, Exp. IV: Individual audio-visual responses for group 3 (average 13 weeks old subjects), when the visual stimuli were permanently present (condition IV-1, ST) and absent (condition IV-2, BL). The audio stimuli were given in a random fashion

Trials Exptal. subjects	1-10	11-20	21-30	31-40	TOTAL
	STRUCTURED		BLANK		
1	67% (6/9)	80% (4/5)	0% (0/3)	67% (4/6)	61% (14/23)
2	78% + (7/9)	67% (6/9)	60% (6/10)	75% (6/8)	69% * (25/36)
3	25% (1/4)	40% (2/5)	29% (2/7)	50% (4/8)	37% (9/24)
4	56% (5/9)	57% (4/7)	50% (4/8)	33% (2/6)	50% (15/30)
	BLANK		STRUCTURED		
5	78% + (7/9)	67% (6/9)	60% (6/10)	40% (4/10)	61% (23/38)
6	25% (1/4)	100% (2/2)	67% (6/9)	37% (3/8)	52% (12/23)
7	67% (2/3)	40% (2/5)	22% + (2/9)	30% (3/10)	33% (9/27)
8	50% (1/2)	100% (2/2)	86% + (6/7)	33% (2/6)	65% (11/27)

*$p < 0.05$ **$p < 0.01$ +$0.05 < p < 0.10$ (tendency)

It can be seen in Table 43 that the responses of the 13 weeks old (on average) experimental subjects do not differ from those which could have been expected by chance during the 4 blocks of 10 trials. It is worth pointing out that 3 subjects (2, 5 and 8) showed a tendency to look towards the sound in the first block of 10 trials of a newly structured perceptual visual field. Subject 2 looked significantly more towards the sound over the 40 trials.

The next table, Table 44, describes the results for group 4, the 19 weeks old (on average) experimental subjects.

Table 44, Exp. IV: Individual audio-visual responses for group 4 (average 19 weeks old subjects), when the visual stimuli were permanently present (condition IV-1, ST) and absent (condition IV-2, BL). The audio stimuli were given in a random fashion.

Trials / Exptal. subjects	1-10	11-20	21-30	31-40	TOTAL
	STRUCTURED		BLANK		
1	90% * (9/10)	70% (7/10)	50% (3/6)	80% (4/5)	74% ** (23/31)
2	75% (6/8)	40% (2/5)	12% * (1/8)	62% (5/8)	48% (14/29)
3	75% (6/8)	29% (2/7)	57% (4/7)	50% (4/8)	53% (16/30)
4	90% * (9/10)	56% (5/9)	57% (4/7)	67% (4/6)	69% * (22/32)
	BLANK		STRUCTURED		
5	22% + (2/9)	87% * (7/8)	40% (4/10)	67% (2/3)	50% (15/30)
6	67% (6/9)	50% (2/4)	37% (3/8)	25% (2/8)	45% (13/29)
7	80% + (8/10)	50% (4/8)	44% (4/9)	17% (1/6)	52% (17/33)
8	67% (6/9)	56% (5/9)	75% (6/8)	62% (5/8)	65% + (22/34)

*$p < 0.05$ **$p < 0.01$ $+0.05 < p < 0.10$ (tendency)

It can be observed in Table 44 for group 4 that subjects 1 and 4 make significantly more eye movements in the direction of the sound in the first 10 trials. Both of those subjects were first given the random auditory stimuli facing a structured visual field. When the same subjects were given the auditory stimuli facing a blank visual field, only subject 2 gives significantly more eye movements in one direction; this time away from the locus of the sound. Of the experimental subjects who were first given the auditory stimuli while facing a blank perceptual field, only one subject (subject 5) gives significantly more eye movements in one direction. These are ipsilateral with the sound in the second block of 10 trials. Over the 40 trials two experimental subjects from the whole group of 19 weeks old (on average) subjects made significantly more eye movements towards the sound (subjects 1 and 4 again).

The next table, Table 45, describes the results for group 5, the 27 weeks old (on average) experimental subjects.

Table 45, Exp. IV: Individual audio-visual responses for group 5 (average 27 weeks old subjects), when the visual stimuli were permanently present (condition IV-1, ST) and absent, (condition IV-2, BL). The audio stimuli were given in a random fashion.

Trials / Exptal. subjects	1-10	11-20	21-30	31-40	TOTAL
	STRUCTURED		BLANK		
1	80% + (8/10)	70% (7/10)	67% (6/9)	57% (4/7)	69% * (25/36)
2	50% (4/8)	80% (4/5)	33% (1/3)	0% (0/0)	56% (9/16)
3	100% ** (9/9)	70% (7/10)	71% (5/7)	50% (3/6)	75% ** (24/32)
4	70% (7/10)	60% (6/10)	20% (1/5)	80% (4/5)	60% (18/30)
	BLANK		STRUCTURED		
5	44% (4/9)	62% (5/8)	60% (6/10)	57% (4/7)	56% (19/34)
6	56% (5/9)	75% (6/8)	50% (5/10)	80% (4/5)	62% (20/32)
7	89% * (8/9)	100% ** (7/7)	75% (6/8)	60% (3/5)	83% ** (24/29)
8	80% + (8/10)	67% (6/9)	60% (6/10)	100% * (5/5)	74% ** (25/34)

*$p < 0.05$ **$p < 0.01$ +$0.05 < p < 0.10$ (tendency)

It can be observed in Table 45 that two subjects have significantly more eye movements in the direction ipsilateral with the sound in the first 10 trials. These are subject 3 for the group which was given a structured visual field first, and subject 7 in the group which was first given the auditory stimuli while facing a blank visual field. This last subject also looks significantly more towards the sound during the second block of 10 trials (11-20). Subject 8 shows a tendency to look towards the locus of the sound in the first 10 trials while facing a blank visual field and gives significantly more eye movements ipsilateral with the sound in the last block of 10 trials (31-40) while facing a structured visual field. Four subjects (1, 4, 7 and 8) give significantly more eye movements towards the sound over the 40 trials in this group of experimental subjects averaging 27 weeks.

An analysis was carried out of the information relating to the direction of the experimental subjects' responses to the first trial and to the direction of their first response. The results are shown in Table 46 where each box of the first trial row contains the total number of experimental subjects over a total possible of 8 per group who responded to the first trial of the experimental session. It indicates the direction of their eye movements in relation to the locus of the sound. Each box of the first response row describes the eye movements of the total number of experimental subjects per group whenever their first response occurred. It indicates the direction of their eye movement in relation to the locus of the sound.

Table 46, Exp. IV: Individual analysis of the experimental subjects' response to the first trial and their first response to the experimental session.

		Structured→Blank		Blank→Structured		TOTAL		TOTAL
		Toward sound	Away from sound	Toward sound	Away from sound	Toward sound	Away sound	
Group 1 Newborn	*1	2/4	2/4	4/4	0/4	6/8	2/8	8/8
	*2	2/4	2/4	4/4	0/4	6/8	2/8	8/8
Group 2 x̄ 7 wk	*1	1/4	2/4	1/4	2/4	2/8	4/8	6/8
	*2	2/4	2/4	2/4	2/4	4/8	4/8	8/8
Group 3 x̄ 13 wk	*1	2/4	2/4	2/4	1/4	4/8	3/8	7/8
	*2	2/4	2/4	2/4	2/4	4/8	4/8	8/8
Group 4 x̄ 19 wk	*1	4/4	0/4	2/4	2/4	6/8	2/8	8/8
	*2	4/4	0/4	2/4	2/4	6/8	2/8	8/8
Group 5 x̄ 27 wk	*1	4/4	0/4	4/4	0/4	8/8 **	0/8	8/8
	*2	4/4	0/4	4/4	0/4	8/8 **	0/8	8/8
TOTAL	*1	13/20	6/20	13/20	5/20	26/40**	11/40	37/40
	*2	14/20	6/20	14/20	6/20	28/40**	12/40	40/40

** $p < 0.01$

Notes :

*1 First trial

*2 First response

It can be seen from Table 46 that those 4 subjects who were first given the auditory stimuli while facing a structured visual field in group 1 (the youngest experimental subjects) respond equally towards and away from the locus of the sound both in their first response and to the first trial. All of the subjects of the same age group who were given a blank visual field first respond to the first trial by looking towards the sound.

Groups 2 and 3 respond by looking equally towards and away from the sound in both conditions during the first trials and in their first response.

The 4 subjects in group 4 who started with a structured visual field look ipsilaterally with the sound in the first trial. Of the 4 subjects who started with a blank visual field, two look towards and two look away from the audio stimulus. All eight subjects in group 5 respond to the first trial (which was also their first response) by looking towards the locus of the sound, regardless of the characteristics of the visual field.

One hundred percent of the subjects in groups 1, 4 and 5 responded to the first trial. In group 2 seventy five percent and in group 3 eighty seven percent responded to the first trial.

Ninety three percent of the subjects responded to the first trial of the experimental session overall for experiment IV. Of these, 70 % responded towards the sound ($p < 0.01$). Seventy percent of first responses of the 40 experimental subjects were also made towards the auditory stimuli ($p < 0.01$).

(iv)b) Perseverance.

Perseverance was studied with the aim of finding out whether the eye movements that occurred had a relation to the locus of the sound, or if the sound acted rather as a trigger for the eye movements.

The results of Exp.IV were re-analysed to find out if the experimental subjects showed in any way that they persevered in the direction of their eye movements. Perseverance was shown if the subjects repeated the direction of the eye movement of their first response, or if they repeated the direction of the eye movement of the first response after the change in the structure of the visual field.

To this end, the responses of the experimental subjects were re-scored taking as the correct response the eye movements in subsequent responses in the same direction as that of the first response (Table 47). A persevered response was also scored if the eye movement in subsequent responses was in the same direction as that of the first response after the change in the structure of the perceptive field, i.e. trials 1 and 21 (Table 49). The experimental subjects were considered to have shown perseverance if they made significantly more ($p < 0.05$) eye movements towards the direction of the trial described above.

Each box in Table 47 contains the number of experimental subjects who persevered out of a possible of 4 per group according to which visual field they were given in the first 20 trials (BL=blank; ST=structured).

Table 47, Exp. IV: Perseverance by individual experimental subjects, according to the experimental condition and age.

	group 1 $\bar{x}$ 30 hr		group 2 $\bar{x}$ 7 wk		group 3 $\bar{x}$ 13 wk		group 4 $\bar{x}$ 19 wk		group 5 $\bar{x}$ 27 wk		TOTAL persevered	
	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST
*1	1/4	1/4	0/4	1/4	0/4	1/4	1/4	0/4	0/4	0/4	2/20	3/20
*2	3/4	1/4	3/4	0/4	2/4	3/4	1/4	1/4	0/4	2/4	9/20	7/20
*T	4/8		3/8		5/8		2/8		2/8		16/40	

Notes :

*1 First 10 trials taking as the correct criteria the first response of the experimental subject.

*2 Overall 40 trials taking as the correct criteria the first response of the experimental subject.

*T Total for the 40 trials.

A total of five subjects in the 5 groups persevered over the first 10 trials. Two were facing a blank visual field and 3 a structured visual field. Of those 5 subjects who persevered, two belong to group 1 (the youngest group) and one each to groups 2, 3 and 4. None of the subjects persevered in group 5, the oldest group.

A total of 16 subjects persevered over the 40 trials. Nine started with a blank visual field and seven with a structured visual field. Subjects displayed perseverance in all the age groups. The three younger groups contained more subjects who persevered than the older groups .

The next table (Table 48), gives the direction in which the experimental subjects persevered in relation to the locus of the first sound. The subjects are grouped according to the characteristics of the visual field. Each box gives the total number of experimental subjects out of the total who persevered per group and condition, and the direction of perseverance; towards or away from the first sound (number of subjects who persevered towards or away from the first sound/total who persevered per group and condition).

Table 48, Exp. IV: <u>Direction of the individual experimental subjects' perseverance, following their first response, according to the experimental condition and for all the groups.</u>

	Experimental subjects who persevered towards the locus of the first sound										TOTAL		
	group 1 $\bar{x}$ 30 hrs		group 2 $\bar{x}$ 7 wks		group 3 $\bar{x}$ 13 wks		group 4 $\bar{x}$ 19 wks		group 5 $\bar{x}$ 27 wks		all groups		TOT
	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	
*1	1/1	0/1	0/0	1/1	0/0	1/1	1/1	0/0	0/0	0/0	2/2	2/3	4/5
*2	3/3	0/1	3/3	0/0	2/2	2/3	1/1	1/1	0/0	2/2	9/9	5/7	14/16

	Experimental subjects who persevered away from the locus of the first sound										TOTAL		
	group 1 $\bar{x}$ 30 hr		group 2 $\bar{x}$ 7 wk		group 3 $\bar{x}$ 13 wk		group 4 $\bar{x}$ 19 wk		group 5 $\bar{x}$ 27 wk		all groups		TOT
	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	
*1	0/1	1/1	0/0	0/1	0/0	0/1	0/1	0/0	0/0	0/0	0/2	1/3	1/5
*2	0/3	1/1	0/3	0/0	1/2	0/3	0/1	0/1	0/0	0/2	1/9	1/7	2/16

<u>Notes</u> :

*1 First 10 trials taking as the correct criteria the first response of the experimental subject.

*2 Overall 40 trials taking as the correct criteria the first response of the experimental subject.

As can be seen in Table 48, most of the perseverance observed during the first 10 trials (four out of five subjects who persevered) occurrs towards the sound and evenly between the two experimental conditions.

Over the 40 trials, 14 of the 16 subjects who persevered did so towards the locus of the first sound. The subjects who persevered towards the locus of the sound in groups 1 and 2 (the youngest groups) were facing a blank visual field (subjects 6/7). Perseverance towards the sound occurred equally between blank and structured visual fields in groups 3 and 4. The two subjects who persevered in group 5 were facing a structured visual field.

The next table, Table 49, gives the number of experimental subjects who persevered after the change in the structure of the visual field. Each box contains the number of 20 trial blocks in which the experimental subjects persevered, out of a posssible of 8 blocks (four experimental subjects with two blocks each) per experimental condition per group (number of blocks in which the subject showed perseverance / 8 blocks per condition).

Table 49, Exp. IV: <u>Perseverance by individual blocks of 20 trials, after the change in the structure of the visual field.</u>

	Total of blocks of 20 trials in which the Experimental subject showed perseverance, by groups.										Total showed perseverance (blocks of 20 trials)	
	group 1 x̄ 30 hrs		group 2 x̄ 7 wks		group 3 x̄ 13 wks		group 4 x̄ 19 wks		group 5 x̄ 27 wks			
	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST
*1	3/8	5/8	2/8	2/8	2/8	3/8	1/8	0/8	2/8	1/8	10/40	11/40
*2	8/16		4/16		5/16		1/16		3/16		21/40	

<u>Notes</u> :

*1 Over all 40 trials, taking as the correct criteria the first reponse given by the experimental subject after the change in the structure of the visual field i.e. trials 1 and 21.

*2 Total for the 40 trials.

The experimental subjects show perseverance in 21 blocks of 20 trials (out of a total of 40) when the change in the visual field is taken into account. There is a decrease with increasing age in the number of blocks in which the experimental subjects persevered.

Table 50 gives the results with respect to the direction of the experimental subjects' eye movements in the 21 blocks of trials where perseverance took place after the change of the visual field. Each box contains the number of 20 trial blocks in which the subjects persevered either towards or away from the locus of the first sound after the change (trial 1 and 21), over the total number of blocks of 20 trials where perseverance occurred.

Table 50, Exp. IV: <u>Direction of the eye movements of the individual experimental subjects who show perseverance after the change in the structure of the visual field.</u>

	Number of 20 trial blocks towards the locus of the first sound.										TOTAL blocks of 20 trials		
	group 1 $\bar{x}$ 30 hrs		group 2 $\bar{x}$ 7 wks		group 3 $\bar{x}$ 13 wks		group 4 $\bar{x}$ 19 wks		group 5 $\bar{x}$ 27 wks		all groups		TOT
	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	
*1	2/3	2/5	0/2	1/2	1/2	2/3	1/1	0/0	1/2	1/1	5/10	6/11	11/21
	Number of 20 trial blocks away from the locus of the first sound.										TOTAL blocks of 20 trials		
	group 1 $\bar{x}$ 30 hrs		group 2 $\bar{x}$ 7 wks		group 3 $\bar{x}$ 13 wks		group 4 $\bar{x}$ 19 wks		group 5 $\bar{x}$ 27 wks		all groups		TOT
	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	BL	ST	
*1	1/3	3/5	2/2	1/2	1/2	1/3	0/1	0/0	1/2	0/1	5/10	5/11	10/21

<u>Note</u> :

*1 Over all 40 trials, taking as correct criteria the first response given by the experimental subject after the change in the visual field, i.e. in the trials 1 and 21.

It can be observed in Table 50 that there are 11 blocks of perseverance towards the sound and 10 away. These blocks are distributed more or less evenly in both experimental conditions throughout the five age groups.

(iv)c) Analysis of the Grouped Data.

The next table, Table 51, analyses the results of the 40 experimental subjects as a group, summing up all responses. Each box shows the total number of sound contingent oculomotor responses ipsilateral and contralateral with the sound, per group and experimental condition.

Table 51, Exp. IV: Grouped data, number of sound contingent oculomotor responses when the visual stimuli were permanently present (condition IV-1, ST) and absent (condition IV-2, BL), presented by groups according to their age and experimental condition. The audio stimuli were given in a random fashion.

Eye movements with respect to the sound		group 1 $\bar{x}$ 30 hrs	group 2 $\bar{x}$ 7 wks	group 3 $\bar{x}$ 13 wks	group 4 $\bar{x}$ 19 wks	group 5 $\bar{x}$ 27 wks
ipsilateral	ST	56 (51%)	52 (53%)	67 (53%)	73 + (57%)	91 ** (69%)
	BL	58 (46%)	43 (54%)	51 (55%)	69 + (57%)	73 ** (66%)
contralateral	ST	54 (49%)	47 (47%)	59 (47%)	54 + (43%)	41 ** (31%)
	BL	69 (54%)	36 (46%)	41 (45%)	52 + (43%)	38 ** (34%)
TOTAL	ST	110	99	126	127	132
	BL	127	79	92	121	111

$*p < 0.05$ $**p < 0.01$ $+\ 0.05 < p < 0.10$ (tendency)

As can be seen in Table 51, the three youngest groups show responses that do not differ from chance. Group 4 shows a tendency to look towards the sound and group 5 looks significantly more towards the sound ($p<0.01$).

The next table, Table 52, analyses the results of the 40 experimental subjects as a group, but divided per 4 blocks of trials and per condition. Each box contains (in brackets) the total number of correct responses over the total number of responses given per group in each experimental condition for a 10 trial block (correct/total). This fraction is also given as a percentage. Each box of the total column gives (in brackets) the number of correct and total responses to the first 20 trials (1-20) for the group which started with a structured visual field, plus the number of correct and total responses to the last 20 trials (21-40) for the group which finished with a structured visual field. This figure is a sum per age group for all the subjects who were given the same experimental condition. The results are expressed as correct responses over total responses. The proportion is given as a percentage.

Table 52, Exp. IV: Grouped data of audio-visual responses, when the visual stimuli were permanently present (conditionIV-1, ST) and absent (condition IV-2, BL), presented by groups according to their age and experimental condition. The audio stimuli were given in a random fashion.

Trials / Subjects		1-10	11-20	Change	21-30	31-40	TOTAL
Group 1 $\bar{x}$ 30 hrs	ST	48% (12/25)	58% (14/24)	BL	47% (14/30)	36% (10/28)	ST 51% (56/110)
	BL	49% (17/35)	50% (17/34)	ST	50% (17/34)	48% (13/27)	BL 46% (58/127)
Group 2 $\bar{x}$ 7 wks	ST	48% (12/25)	48% (12/25)	BL	50% (11/22)	53% (10/19)	ST 53% (52/99)
	BL	57% (13/23)	60% (9/15)	ST	55% (16/29)	60% (12/20)	BL 54% (43/79)
Group 3 $\bar{x}$ 13 wks	ST	61% (19/31)	62% (16/26)	BL	43% (12/28)	57% (16/28)	ST 53% (67/126)
	BL	61% (11/18)	67% (12/18)	ST	57% (20/35)	35% (12/34)	BL 55% (51/92)
Group 4 $\bar{x}$ 19 wks	ST	83% ** (30/36)	52% (16/31)	BL	43% (12/28)	63% (17/27)	ST 57% + (73/127)
	BL	59% (22/37)	62% (18/29)	ST	49% (17/35)	40% (10/25)	BL 57% + (69/121)
Group 5 $\bar{x}$ 27 wks	ST	76% ** (28/37)	69% * (24/35)	BL	54% (13/24)	61% (11/18)	ST 69% ** (91/132)
	BL	68% * (25/37)	75% ** (24/32)	ST	61% (23/38)	73% * (16/22)	BL 66% ** (73/111)

*$p < 0.05$ **$p < 0.01$ + $0.05 < p < 0.10$ (tendency)

As can be observed in Table 52, the subjects' eye movements for group 1, 2 and 3 (the youngest groups) are not different from that which we could have expected from chance. The ocular movements are displayed equally both towards and away from the auditory stimuli for the blank and structured perceptive field. Nine weeks old (on average, group 4) subjects show significantly more eye movements towards the sound in the first 10 trials while facing a structured visual field. Over the total of 40 trials, subjects facing both a blank and a structured visual field show a tendency to respond in the direction ipsilateral with the sound. The subjects in group 5 (the oldest group) show significantly more eye movements in the same direction as the sound during the first 20 trials of the experimental session for both blank and structured visual fields. Only the subjects facing a structured visual field showed coordination and that only in the last 10 trials of the experimental session in the second 20 trials (21-30) following the change in visual field. Both experimental conditions show significantly more eye movements towards the sound over the 40 trials.

Fig. 11 gives a graphic representation of the total column of Table 52. It shows the total and correct number of responses for each age group according to the experimental conditions.

Fig. 12 gives a graphic representation of the figures in brackets of Table 52. Results of trials 1-10 and 11-20 for the same experimental condition have been summed, as have been trial 21-30 and 31-40 for the same experimental condition per group.

Fig. 13 also gives a graphic representation of the data in Table 52 but in a proportional form.

Fig. 11, Exp. IV: Grouped data, total and correct audio-visual responses in the experimental conditions when the visual stimuli were permanently present (condition IV-1, ST) and absent (condition IV-2, BL), presented by groups according to their age and experimental conditions, in 40 trials block. The audio stimuli were given in a random fashion.

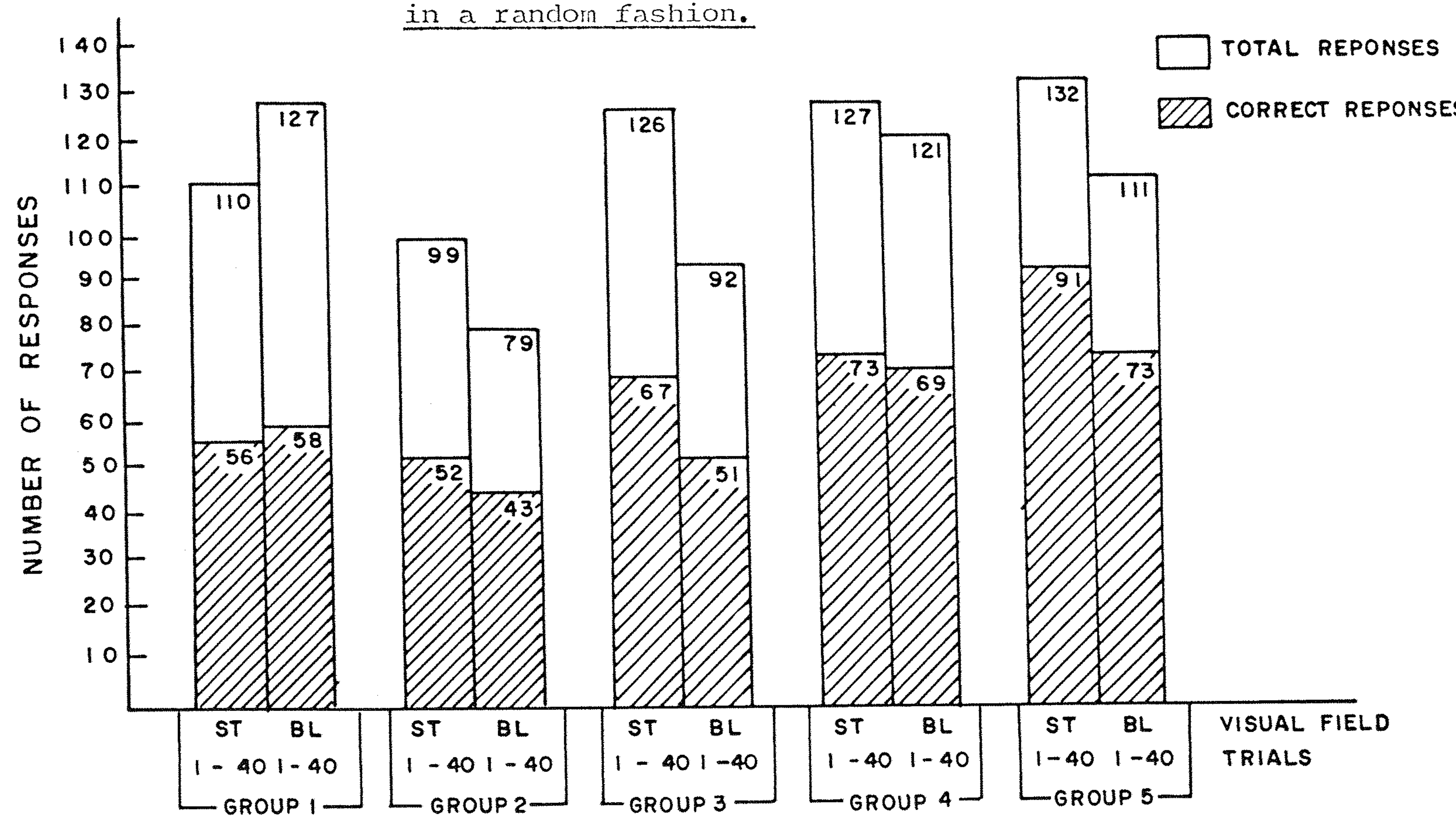
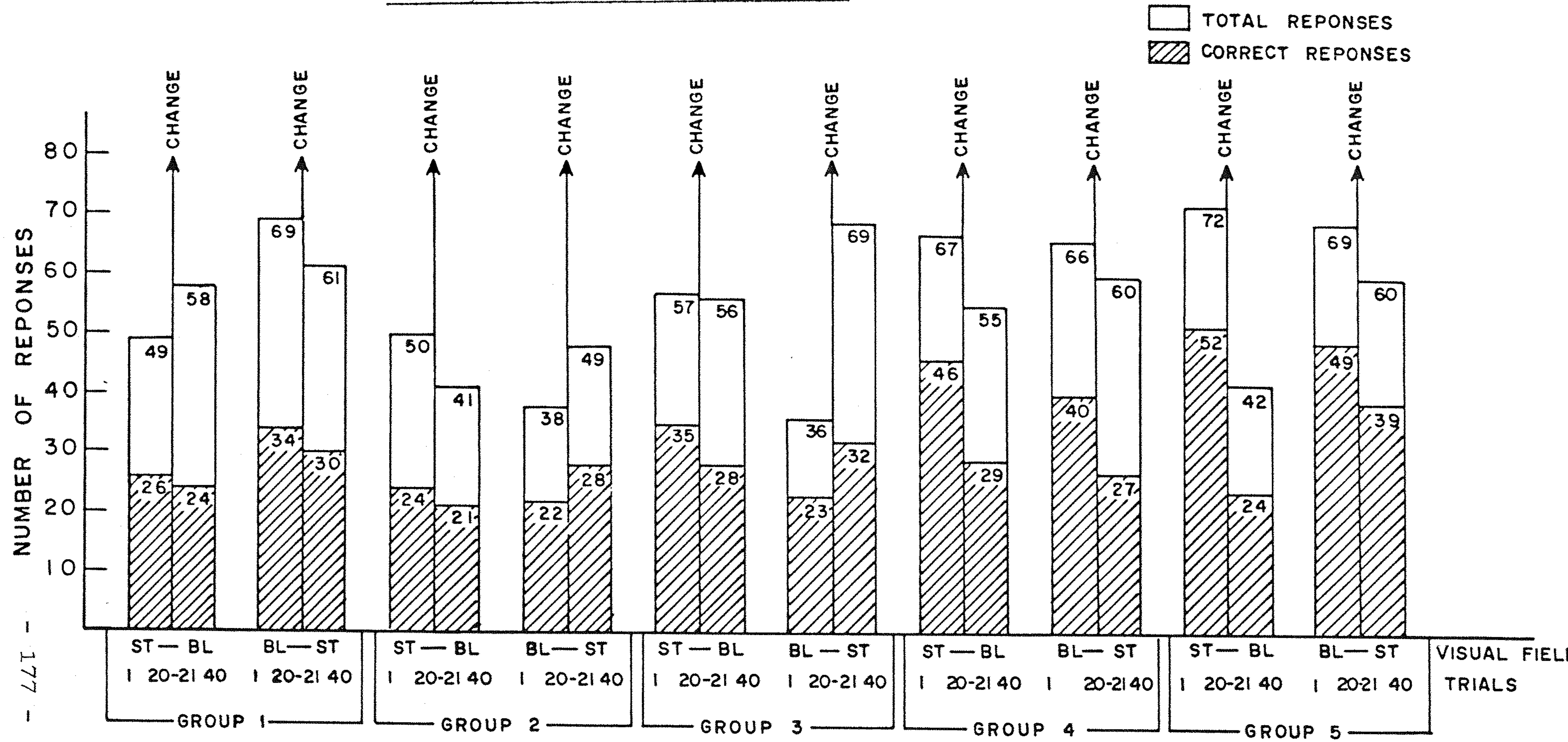
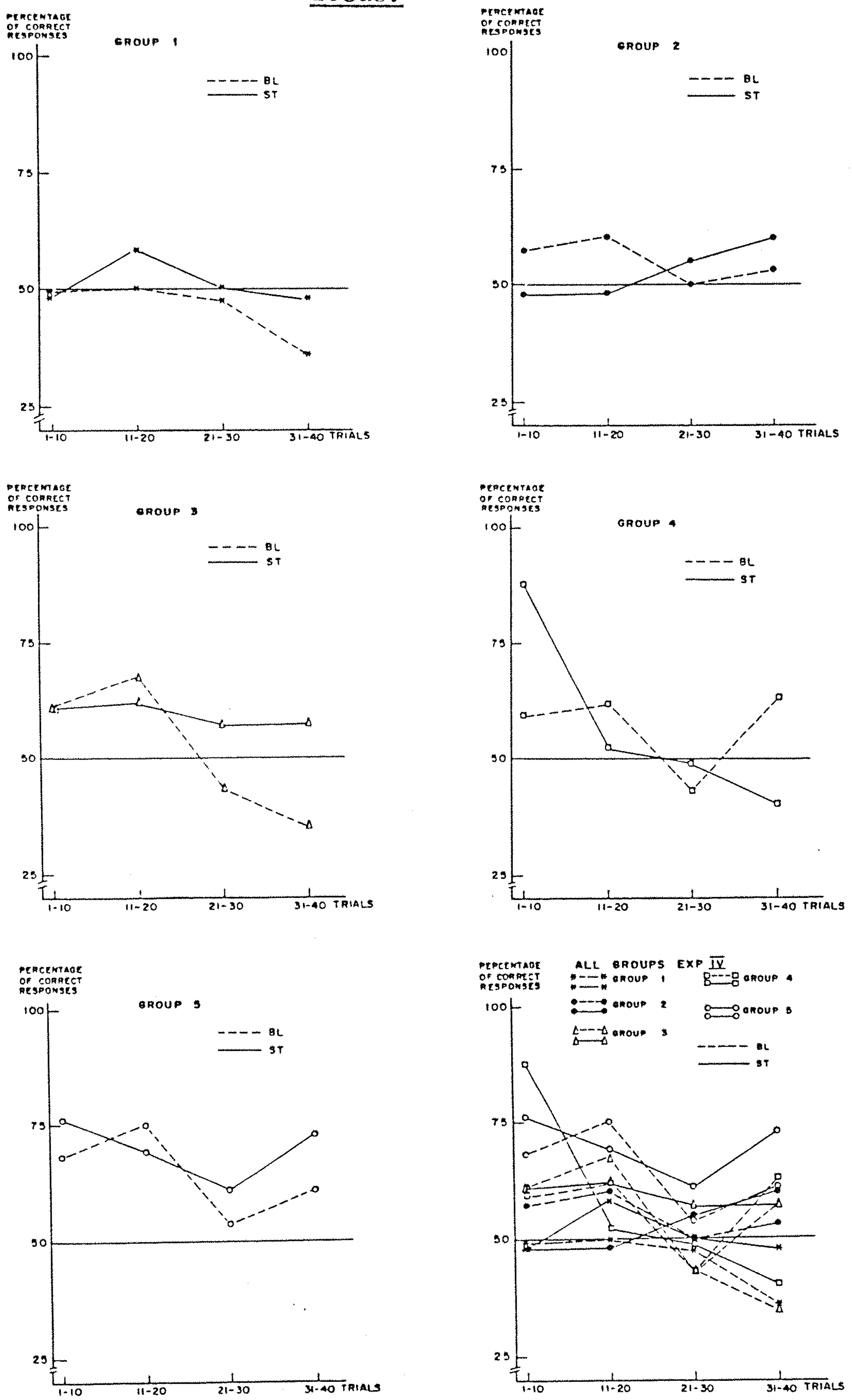


Fig. 12, Exp. IV: Grouped data, total and correct audio-visual responses in the experimental conditions when the visual stimuli were permanently present (condition IV-1 ST), and absent (condition IV-2, BL), presented by groups according to the age and experimental conditions, in 20 trials block. The audio stimuli were given in a random fashion.



As can be observed in Fig.12, there is a variation for all groups in the total number of responses given by the experimental subjects after a change in the visual field stimuli. There is a decrease in the correct and total responses after a change from a structured to a blank visual field for all the groups except group 1. When the reverse change occurrs from blank to structured visual field, there does not seem to be a clear pattern of change in correct and total responses.

Fig. 13, Exp. IV: Proportion of sound contingent eye movements ipsilateral with the auditory locus.



(iv)d) Further Statistical Analysis.

An analysis was carried out to ascertain if there were significant differences between the proportion of correct and incorrect responses, (a) within the 2 experimental conditions per age group, and (b) between the 5 age groups.

Table 53, Exp. IV: Average number of correct, incorrect and total responses, per experimental subject, per condition for all 5 age groups.

	STRUCTURED				BLANK				TOTAL	
Age groups	N	correct $\bar{x}$±SD	incorrect $\bar{x}$±SD	total $\bar{x}$±SD	N	correct $\bar{x}$±SD	incorrect $\bar{x}$±SD	total $\bar{x}$±SD	total correct $\bar{x}$±SD	total incorrect $\bar{x}$±SD
group 1	8	7±2	7±2	14±2	8	7±2	9±4	16±4	14±2	15±3
group 2	8	7±3	6±2	12±3	8	5±2	5±2	10±3	12±4	10±2
group 3	8	8±3	7±3	16±4	8	6±4	6±3	12±5	15±6	13±4
group 4	8	9±4	7±3	16±3	8	9±2	7±2	15±3	18±4	13±3
group 5	8	11±3	5±1	17±3	8	9±5	5±2	14±5	21±5	10±3

Notes:

Figures rounded up to the nearest whole number.

The t test for independent samples was applied to the data (a) within the 2 experimental conditions (blank and structured) per age group. There was found to be a non-significant relation for all ages groups. In other words, the characteristics of the visual field did not seem to influence the number of correct or incorrect responses given by the experimental subjects. The analysis of correct and incorrect responses independent of the characteristics of the visual field found a non-significant relation for the 3 youngest groups (1, 2 and 3), but a significant relation ($p < 0.02$) for group 4 and group 5 ($p < 0.01$).

Table 54, Exp. IV: Average number of total ($\bar{x}t$) and average number of correct ($\bar{x}c$) responses per experimental subject for all age groups.

group 1	group 2	group 3	group 4	group 5
$\bar{x}t$ 30 $\bar{x}c$ 14	$\bar{x}t$ 22 $\bar{x}c$ 12	$\bar{x}t$ 27 $\bar{x}c$ 15	$\bar{x}t$ 31 $\bar{x}c$ 18	$\bar{x}t$ 30 $\bar{x}c$ 21

Notes :

Figures rounded up to the nearest whole number.

The variance (b) between age groups was found to be significant for both the number of correct responses ($p < 0.01$, $F(4-35) = 4.24$) and the total number of responses ($p < 0.05$, $F(4-35) = 3.53$).

The t test was applied for the correct and total number of responses between all the age groups. The results were found to be significant ($p < 0.02$) only for group 2 when comparing it with groups 1, 4 and 5 for the total number of responses. Groups 1, 4 and 5 gave more total responses than group 2.

Group 1 gave significantly fewer correct responses than group 4 ($P < 0.05$) and group 5 ($p < 0.01$).

Group 2 gave significantly fewer correct responses than group 4 ($p < 0.002$) and group 5 ($p < 0.002$).

The experimental subjects taking part in this study displayed different characteristics as has already been pointed out in Table 40. The experimenter thought it necessary to find out if the difference in the eye movements' patterns could be caused by the experimental subjects' characteristics, and not by the experimental conditions being manipulated. To this end the t test was carried out for the correct and total responses of the experimental subjects, and an analysis of variance was made for the drugs variable.

The subjects were divided according to the following intervening variables (as described in Table 40) within each age group.

- sex (male Vs females),
- apgar (low <6 Vs high ≥ 6),
- birth weight (low <2700 grs Vs high ≥ 2700 grs),
- length of labour (short <6 hrs Vs long ≥ 6 hrs),
- birth order (primipara Vs multipara),
- drugs given to the mother before labour; (no drugs Vs. Pethidine and others Vs Epidural and others).

Table 55, Exp. IV: <u>Average number of correct ($\bar{x}c$) and average number of total ($\bar{x}t$) responses per experimental subjects, grouped according to their characteristics within each age group.</u>

		SEX		APGAR		BIRTH WEIGHT		LENGTH OF LABOUR		BIRTH ORDER		DRUGS		
		M	F	low	high	low	high	short	long	p	m	n	p	e
Group 1	$\bar{x}t$	32	29	30	30	-*	30	27	33	30	29	33	28	29
	$\bar{x}c$	16	14	15	11	-*	14	13	16	11	15	14	14	15
Group 2	$\bar{x}t$	25	20	–	–	-*	22	–	–	22	22	22	26	19
	$\bar{x}c$	14	10	–	–	-*	12	–	–	12	12	11	15	9
Group 3	$\bar{x}t$	27	28	–	–	-*	27	–	–	30	20	30	-*	21
	$\bar{x}c$	15	15	–	–	-*	15	–	–	16	12	20	-*	12
Group 4	$\bar{x}t$	32	30	–	–	31	34	–	–	32	30	32	30	32
	$\bar{x}c$	19	14	–	–	17	22	–	–	19	16	19	18	17
Group 5	$\bar{x}t$	33	26	–	–	-*	30	–	–	33	24	32	29	33
	$\bar{x}c$	23	16	–	–	-*	21	–	–	24	17	19	20	25

<u>Notes</u> :

-* no experimental subjects in this category.

– no information available, see Table 40.

BIRTH ORDER (p)rimipara
(m)ultipara

DRUGS (n)o drugs
(p)ethidine and others
(e)pidural and others

The results of the t test showed significant results for some of the variables. Males in group 5 showed significantly more ($p < 0.05$) correct responses than females. Experimental subjects from group 3 whose mothers received no drugs before labour made significantly more correct responses ($p < 0.05$ F (1-6) =4.74) than subjects whose mothers received Epidural and other drugs before labour. Experimental subjects in group 4 whose mothers were primiparas gave significantly more total responses (P< 0.05) than subjects whose mothers were multiparas.

If all the experimental subjects had responded to each and all of the auditory stimuli, there would have been a total of 1600 responses. However, a total of 1124 responses were actually given (70%).

Of the 1124 responses given, 538 were to the left and 591 to the right. The binomial test indicated that there was not a significant directional bias in spite of a difference of 53 responses to the right.

(v) C O N C L U S I O N S.

(v)a) Conclusions on the Analysis of Individual Data.

The results per individual experimental subject for group 1 (newly born subjects, Table 41) showed that no experimental subjects produced significantly more eye movements towards or away from the random sound over the 40 trials. One experimental subject looked significantly more towards the locus of the randomly played sound in the second block of 10 trials (11-20) while facing a blank visual field.

Group 2 (average 7 weeks old experimental subjects, Table 42) did not contain any experimental subjects who displayed significantly more eye movements towards or away from the sound either over the 40 trials or during the experimental session.

Group 3 (average 13 weeks old experimental subjects, Table 43) gave no evidence of coordination in the experimental subjects during the 4 blocks of the experimental session. One experimental subject showed significantly more eye movements ipsilateral with the sound over the 40 trials. This subject was given the random auditory stimulus while facing first a structured visual field, followed by a blank visual field.

Group 4 (average 19 weeks old experimental subjects, Table 44) contained 4 experimental subjects who displayed coordinated eye movements in one of the four blocks of 10 trials. Two of these subjects showed coordination during the first 10 trials block while facing a structured visual field. Their coordination was ipsilateral with the locus of the random sound. The other 2 experimental subjects showed coordination when facing a blank visual field, one in the second block of trials (11-20) and the other in the third (21-30) block of 10 trials. One subject showed coordination towards the random sound and the other away. Over the 40 trials 3 experimental subjects showed significantly more eye movements in one direction. These subjects' eye movements were towards the random sound and received the auditory stimulation while facing first the structured and then the blank visual field.

Group 5 (the oldest group, average 27 weeks old experimental subjects, Table 45) contained 3 experimental subjects who displayed coordination during part of the experimental session. Eye movements were all ipsilateral with the locus of the random sound. Two of these subjects showed coordination during the first block of 10 trials; one facing the blank and the other the structured visual field. The third experimental subject showed coordination during the last block of 10 trials and while facing a structured visual field. Four experimental subjects showed coordinated eye movements over the 40 trials and ipsilateral with the locus of the sound. Two of these subjects started with a structured and two with a blank visual field.

As can be seen from the individual analysis of the experimental subjects' responses in Experiment IV, no coordinated eye movements appeared until the third month and then only one subject out of 8 was able to produce this coordinated eye movement ipsilateral with the locus of the randomly played sound. Two subjects in the 4½ month old group presented significantly more eye movements that were towards the sound. The experimental subjects who produced the coordinated eye movements in both these groups were facing the structured visual field during the first 20 trials of the experimental session. The experimental subjects in the oldest group who showed coordination did so in both experimental conditions (blank and structured).

Ninety three percent of the experimental subjects responded to the first trial, seventy percent ipsilateral with the sound (Table 46). The direction of their eye movements was not different from chance for all but the oldest group, whose subjects looked towards the sound. The youngest and the oldest groups' first responses while facing the blank visual field were all towards the sound, as were those of the two oldest groups' responses while facing the structured visual field.

When we look at the perseverance of the individual experimental subjects (Tables 47 and 48), we find that 5 experimental subjects out of 40 persevered over the first 10 trials, 2 facing the blank and 3 the structured visual field. Four of these subjects persevered towards the locus of the first auditory stimulus they were given, and one away from it. Sixteen experimental subjects out of 40 persevered over the 40 trials. Nine were faced first with a blank and seven with a structured visual field. Fourteen persevered towards the locus of their first auditory stimulus and two away.

Twenty one experimental subjects showed perseverance over 40 trials when the results were analysed taking into account the change in the structure of the visual field after 20 trials (Tables 49 and 50).

These 21 subjects looked towards the locus of the random sound in slightly more than half of the blocks of 20 trials.

(v)b) Conclusions on the Analysis of Grouped Data.

If we look at the grouped data for Experiment IV (Tables 51 and 52) we can see that the overall responses for the 4 youngest groups divided according to the experimental conditions of the visual field are not different from that which we could have expected from chance. The experimental subjects in the oldest group over the 40 trials looked significantly more ($p<0.01$) towards the random sound. It can be seen that the first 20 trials generated the majority of the coordinated eye movements, whatever the particular characteristic of the visual field.

It seems that the presentation of a sound in a random fashion in conjunction with either a blank or structured visual field to subjects below 6 months of age is not enough to elicit eye movements coordinated with the sound. However the 4½ month old subjects have a clear tendency towards eye movements coordinated with the locus of the sound.

The number of total and correct responses did not vary within each age group as a reflection of the characteristics of the visual field (Table 53). The total of responses per age group independent of the structure of the visual field was found to be at chance level for the first 3 age groups, but significant for groups 4 and 5.

Group 2 gave significantly fewer total responses than groups 1, 4 and 5 (comparing the number of total and correct responses between the different age groups Table 54). Group 1 and 2 gave significantly fewer correct responses than groups 4 and 5.

Three out of 36 comparisons were found to be significant when the individual experimental subjects' characteristics were studied (Table 55). It can be predicted that the individual characteristics did not bear great responsibility for the different pattern of responses per age group and experimental condition because of the very small number of experimental subjects in some of these comparisons (3 and 4 cases).

A total of 1124 responses was obtained out of a possible total of 1600 (70% response rate). Of those 1124 responses, 538 were to the left and 591 to the right; a non significant directional bias.

GENERAL FINDINGS AND THEIR RELATION TO OUTLINED THEORIES

The main question left open in the introduction to this thesis was the relation between the sensory systems (in particular the auditory and visual) at birth and their development during the first six month of life in the human neonate.

There is plenty of experimental evidence as the result of the series of experiments carried out and reported in detailed here, to support the idea that the auditory and visual systems from the early newborn period are not independent.

This coordination between the sensory systems is, however, difficult to demonstrate and is statistically significant only under particular stimulus configurations.

If the hypothesis of the primitive unity of the senses is correct and coordination is innate, experimental subjects should show ipsilateral responses to sound from the first trial. However, the results reported in this series of experiments with 112 experimental subjects indicate that the first responses were at chance level. This failure to respond in a coordinated manner from birth could be explained in the light of what other authors have reported in the literature as the non-attractive meaningless characteristics of the auditory stimulus used in the experimental situations reported here. Turkewitz et al (1966) found that infants failed to respond to pure tones and recommended the use of brief white noise stimuli, or of tones of longer duration. Ashton (1971) suggested the use of low frequency waves and Hutt et al (1968) found also that this type of auditory stimulation elicited the maximum number of behaviour responses from the newborn. Carpenter (1974) reported that the infants responded better to pattern (square wave) tones and to the human voice than to pure sine wave tones.

The results of the analysis of the first response given by the experimental subjects do not seem initially to support the theory of the sensory mapping of auditory and visual senses in a pre-existing spatial framework without any environmental involvement. We can say that we were unable to elicit an innate first response under the particular experimental conditions described earlier, but we can not state that one does not exist.

The failure to coordinate from the first response may be due to the particular characteristics of the sound used here (including its short duration) as has already been explained above.

When we look at the results of repeated stimulation, we find that the presence of a visual target in the visual field of view elicited oculomotor coordination in the course of the experimental session. This result does not support the classical theory stating the independence of the audio and visual perceptual systems.

The newborn human infants were able to produce consistent spatially coordinated oculomotor responses contingent with a sound, given experimental conditions where an auditory stimulus was given in blocks and a visual field was structured in some way. The auditory stimulus was given a stable spatial characteristic by being presented in blocks of 10 trials. The locus of the sound remained unchanged during these 10 trials. The time during which this location remained unchanged may have been sufficient for the experimental subjects to coordinate their responses.

It may be that the formation of an auditory model requires a minimum of time during which the sound itself is heard and its locus remains permanent.

A permanently structured visual field enables the visual system to prevail over the information provided by the auditory system. A distinctive visual target is very useful in fixing the sound's position when experimental subjects have to remember the locus of a audio stimulus of short duration.

Two reference systems seem to be used in the localization of a sound; one internal with respect to the body of the infant himself (egocentric) and another considering the characteristics of the outside world (allocentric). If the neonate moves, the allocentric reference system will still allow him to perform precise auditory localization by using the visual system as support. When the sound and visual target provided conflicting information in the experiments, the infants looked towards the visual target even more than when the information was congruent. The spatial dislocation between the sound and the visual targets and the increase in eye movements towards the target could be explained by a simple dishabituation hypothesis. The stable allocentric visual locus may take priority over the memory of the position left by the short sound. Lyons-Ruth (1974) and McGurk et al (1977) proposed that when there was an intermodal conflict, babies' behaviour could be the result of a visual capture by the visual stimulus.

Under normal circumstances sounds are elicited by objects in the visual space. An innate spatially-organized link between the auditory and the visual system would mean that a search with eye movements for the object which elicited the sound will generally find that object. The repetition of this pattern of association could have established a mutually supportive system.

An infant may forget a stimulus and lose the goal of his response during the time needed to organize this response. It is very important for the infant to remember the initial auditory locus during this early period when the spatial information is starting to be structured. The initial lack of coordination may be avoided by allowing the visual system to support auditory memory so that the sound appears to come from an object that is simultaneously visible (Bryant et al 1972).

The newborn babies in Experiment III were faced with two permanent visual targets but looked at only one (contingent and ipsilateral with the sound). It therefore cannot be argued that the experimental subjects simply look towards an available visual target.

It is very likely, in the light of this experimental evidence, that oculomotor coordination goes beyond the purely reflexive level.

The effect of the structure of the audio stimuli is emphasized by the results of the two groups of newborns who were given the same visual configurations but a different organization of sound. The group that received blocks of sound and two permanent visual stimuli (condition III-1) displayed coordination, but the group that received random sound and two permanent visual stimuli (condition IV-1,ST) did not. The newborn human infant may first need to find a mechanism to locate the events that have occurred, and with which he may construct a model with respect to its spatial characteristics.

With respect to the development of the audio-visual coordination during the first six months of life, experimental subjects were not able to show consistent spatial coordination between their oculomotor responses and the locus of a randomly presented sound in the cross-sectional study (Exp. IV) until they reached 4½ months of age. As the locus of the sound changed with each trial in this condition, the newborn infant did not have a stable basis for the construction of a model. The results indicated that the young infant was not capable of coordinated eye movements under random auditory stimulation. These findings are consistent with Lyons-Ruth (1977) who suggested that infants perceive sound as an attribute of a specific object by about 4 months, when they seem to relate knowledge obtained in the auditory mode to information obtained through the visual mode.

The significant drop in the number of correct responses between the youngest groups of subjects (as observed in the 1½ month olds compared to the newborn group) was also reported by Field et al in 1980 when they found that the performance of the turning response in the newborn was better than in older subjects and declined between the 1st. and the 3rd. months. There was a marked increase at 2 months in the number of trials in which there was no response in the experiments described. Although looking and listening activities may be coordinated from birth, the visual and auditory experiences begin to be integrated perceptually at about 3 months. The sound to which an infant initially listens may act as a trigger to look and find. The infant may discover the visual target even by accident. With further experience he may listen to a sound and look to find something specific. Not even the presence of two permanent visual targets gave the young groups who were given a random sound enough information from which to elaborate coordinated responses as there was no permanent feature in the locus of the sound.

The change observed in the pattern of responses between the 5 groups of infants in this cross-sectional study during the first 6 months of life reflects the normal maturational development of the newborn human baby.

The results of the analysis of perseverance do not show a clear tendency. Experimental subjects showed perseverance over all conditions, especially when two visual targets were present and the infants who received random sound were young. It may be that the newborn infant expects a sound that has been produced in a fixed locus in space to remain in its locus if nothing else has changed in the stimuli situation.

The difference between the results reported in this thesis and the ones obtained by Butterworth and Castillo (1976) with reference to contralateral looking may be explained by the changes introduced in the stimuli situation. The sound intensity and general luminosity were reduced in the current experiments. The duration of the audio stimuli was doubled.

Hittelman and Dickes (1979) found in their studies that female neonates revealed a greater sensitivity to auditory stimulation than did male. No differences in the patterns of responses due to the sex of the experimental subjects were found in the experimental evidence of this thesis.

Crassini and Broerse (1980) and McGurk et al (1977) reported that their experimental neonates displayed a statistically significant low response rate. This was not the case in the experiments reported in this thesis. Here the overall response rate was 67%.

Jones and Kabanoff (1975), have proposed a theory that auditory localization depends upon a specific eye movement directed towards the target. They argued, following Kinchla and Allan (1969) and Warren (1970) that eye movements may be involved in auditory localization. They found that auditory localization is less accurate in the absence of eye movements. Repeated stimulation coming from an unchanging locus may allow the infant to organize a consistent eye movement in response to a sound thus stabilizing auditory position memory. Stability of auditory memory would increase if the auditory stimulation were localized with respect to a visual target in the perceptive field. The eye movements could therefore serve to confirm the initial auditory judgement.

The newborn experimental subjects taking part in these experiments have to find a way to locate the events that have occurred in the environment and reflect their spatial characteristics. Warren (1970) has suggested that most subjects develop a system of visual coordinates (a visual map) which they use to assess the spatial location of stimuli received through any perceptual system. These stimuli would be integrated and assimilated in the internal configurations that allow the infant to understand the event. The audio-visual coordination found in the experimental conditions when a visual target is available corroborates this theoretical position.

Some degree of interdependence must already exist between the senses from the beginning of their development in order to explain early audio-visual coordination as seen in these experiments. Butterworth (1981) talks of the possibility of an innate functional relationship between the auditory and the visual systems. The basic unitary spatial framework detects intermodal equivalence of the senses as soon as crossmodal information is available. Information obtained from any of the senses at a certain level of information processing integrates into a unitary spatial framework.

The newborn should have a predisposition to be relatively more responsive to functionally relevant complex auditory stimuli such as those provided by speech than to the infrequently represented auditory stimuli such as pure tones. The newborn infant seems more likely to respond to few stimuli coming from a stable position in his environment, rather than to a great variety of moving stimuli.

In the light of this evidence and before being able to make definitive statements, it is necessary as the next step to carry out more experiments in which the auditory stimulus is the human female voice (to ensure neonate responsiveness from the first trial). The visual stimulus could be a human female face. These more valid and naturally occurring stimuli may allow the human neonate to display to us its fullest and most complex innate capacities.

The experimental evidence of this thesis supports the theory that the auditory and visual systems are not completely independent from birth. The evidence of a spatially organized connection between the two systems could be explained by the theory of innate functional relationship described above.

LIST OF FIGURES.

L I S T   O F   T A B L E S.

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