Chapter 5
Laying the Foundations of an Analysis of Intelligence

1. Psychometrics and Autism

To evaluate earlier theories, it was sufficient to be familiar with the characteristics of autism alone. But to transcend the shortcomings of those theories and construct a new one will require an understanding of human cognition and its development. The autistic child is a human being. His mind is a human mind, though certainly not a typical one, and its development, though atypical, is nonetheless a variety of human cognitive development. To understand in what ways the autistic mind is similar to other minds and in what ways it differs requires a broad understanding of intelligence, of the various functions involved and their relationships to one another. In the introduction and in the preceding chapters, we discussed questions of the origin of human intelligence and the nature of the mechanisms by which it is performed. We have emphasised the need to reevaluate current theories and revise them when necessary. Here, however, we shall not be concerned with those questions. We shall be dealing instead with the even more fundamental question of what intelligence is. The discussion in this chapter will therefore be, for the most part, independent of questions of heredity and development, and acceptable, at least in principle, to adherents of all schools.

Traditional analyses of intelligence were motivated by attempts to predict academic success. Intelligence tests were composed to be administered to school children to determine what academic level they could be expected to achieve and whether they should be placed in normal, accelerated or remedial classes. The accuracy of those tests was measured by their statistical correlation with children's eventual achievements. They therefore addressed only those kinds of intelligence that had bearing on subjects studied in school. After a while, however, the measurement of intelligence and the ranking of individuals by performance on such tests began to be applied beyond the context of education, and came to be seen as having social and economic significance. This extension brought sharp criticism for the implication that intelligence score was a measure of an individual's worth, and that children who ranked low were globally inferior. In response, new analyses were constructed that included areas that, while not of significant value academically, were valuable in other life situations. Since a child who did poorly in school and ranked low on intelligence tests might nonetheless excel in some of these areas, his overall worth should not be considered less than that of his more academically-able companions.

But, while these remedied the neglect of certain important kinds of intelligence, their approach was fundamentally the same. Like the earlier analyses, their concern was evaluation and comparison of individuals, even though the goal of these later analyses was not to actually rank them but rather to show that the rankings made by previous systems were not valid. None were primarily concerned with analysing the fundamental question of what intelligence is. Their definitions of intelligence were based more on what was achieved than the underlying process of achieving it. Narrower ones generally emphasised abilities involved in solving problems, broader ones those involved in adapting successfully to the environment. The difference between the original purely academic analyses and the later revised systems was which human activities were of value. The question of defining intelligence was secondary.

We, however, have a radically different goal. We are not concerned with judging or comparing individuals, so we are not interested in quantifying, measuring or ranking. Our main question is a qualitative, not a quantitative one. We want to identify which kinds of mental faculties are abnormal in autism and in what ways. Our approach is therefore fundamentally different from theirs. For us, defining intelligence is primary and central. All of our subsequent analysis will hinge on that definition. It is, indeed, a fundamentally different kind of definition. But it is not like a dictionary definition whose purpose is to get as close as possible to how the word is actually being used, but an artificial scientific definition, whose purpose is to identify the concept that will be most meaningful and useful for the inquiry we are about to make. We are not claiming, therefore, that the definition we are constructing is the only correct one, and certainly not that that is the current accepted usage of the word "intelligence", but that, from among the various acceptable ones, it is the one that will best serve our purposes. Composing and refining a suitable definition will therefore be not only a preparation for analysis but the beginning of analysis itself.

1.1 Defining Intelligence

Intelligence is, first of all, a *quality of a living organism*. Although it is sometimes used to describe machines, that use is derived by analogy to living beings. What sort of quality is it? Of the various qualities of living organisms, some, such as size and weight, relate to their *physical structure*, while others, such as body temperature, relate to their *life functions*. Intelligence is among the latter. It relates to the specific subset of life functions which we will refer to as *behaviour*. Of the various kinds of behaviour performed by living organisms, some are intelligent and others are not. The category of intelligent behaviour includes such diverse activities as speech and tool use in humans, and nest building and hunting in animals. There are other behaviours, such as yawning and scratching, whether performed by humans or animals, that are not intelligent. Intelligent behaviour is therefore a subset of all behaviour, which is a subset of life functions, which is a subset of qualities of living organisms.

One might object that intelligence should not be limited to behaviour. There are other activities such as *observing*, *analysing*, *predicting* and *contemplating* that are certainly intelligent, but do not fit the paradigm concept of behaviour because they are internal and cannot be observed directly. So before identifying the criteria by which a behaviour may be deemed intelligent, let us examine the concept of behaviour itself to determine how it may be defined to include these *covert activities*. One way would be to include any activity that subsequently results in overt action. The covert activity would then be considered to have been part of the later overt behaviour. A more direct approach would be to define behaviour broadly as referring to any activity of an organism, whether overt or internal. This problem could have been avoided entirely by substituting the word "activity" for "behaviour" in our definition, and indeed it makes no difference which one is used. We have chosen to retain the term "behaviour" and extend its definition this way because in most of our discussion this term will be more appropriate. What is important is that intelligence is not a passive quality but always involves some sort of activity, something that the organism does. Even internal, unobservable activities such as choosing and planning are not static qualities of an organism, but activities that it performs.

We shall therefore define intelligence as *the ability to perform certain kinds of behaviour*, which we call "intelligent behaviour". An organism need not be currently performing an intelligent behaviour to be considered intelligent as long as it could, under the appropriate conditions, perform it. It will therefore suffice to define intelligent behaviour, from which the definition of intelligence will follow directly.

1.11 Purposeful

What kinds of behaviour can be considered intelligent? There are certain paradigm behaviours, such as those mentioned above, that are clearly included, but what are the implicit criteria of this inclusion? What qualities must a behaviour have to be considered intelligent? The first quality that distinguishes intelligent behaviour is that it is *purposeful*, it is oriented toward a goal. One would not consider the twitching of a cat's tail an intelligent behaviour. Need that orientation, however, be conscious? Most paradigm cases do, indeed, involve consciousness. Whether it is a human being playing chess or a rat escaping from a trap, they are aware of the problem and are making an effort to solve it. Initially, therefore, one is inclined to assume that intelligence must be consciously mediated. Restricting the definition of intelligence in this way, however, would exclude much animal behaviour, such as that of a spider spinning a web or of a bee dancing or following the dance of another bee. Though these lack consciousness, they are certainly purposeful. Were we to exclude them because they lack consciousness, we would have to exclude not only all the behaviour of lower animals, but also much of the behaviour of human beings, such as the cyclist's maintaining his balance, the movement of the pianist's fingers as they strike the correct keys, or the speaker's recall of the appropriate words. These and many other kinds of human behaviour are undoubtedly intelligent but are not consciously mediated. While it could be argued that maintaining balance on a bicycle is simply a skill, acquired by the mechanisms of classical conditioning, and therefore does not qualify as intelligence, no such argument can be made with respect to the complex activities of speaking and comprehending language.

These are not isolated examples. On the contrary, all conscious intelligence involves a consciousless foundation. The hunter does not consciously think of how to hold his bow and aim his arrow. Though we use language consciously and for conscious purposes, the ability to produce the correct words at the right moments, to conjugate them and arrange them correctly, is all done without conscious control. When an English speaker wants to talk about a tree, the word "tree" comes to his tongue. He need not even imagine a picture of a tree. Words follow directly and effortlessly from thoughts.

Since conscious control is not one of the criteria of intelligence, the concepts of "purpose" or "goal" cannot be equated to "intention". The organism need not be aware of the result or be trying to achieve it. "Purpose" means, rather, that the behaviour has some beneficial effect, and that the organism tends to perform it at the appropriate time. It is in this sense that the processes, conscious or otherwise, that control the performance, are considered to be directed to this goal.

That is not to say, however, that consciousness is irrelevant to purpose. Behaviours that are performed consciously can be considered purposeful simply by virtue of achievement of intention even without any practical benefit. Thus when an animal directs its leap so that it lands on a specific spot, even if it derives no particular benefit from getting there, its action is nonetheless purposeful. Chasing balls is not actually beneficial for a kitten, other than in the sense of development of hunting skills, but in that the animal has an intention which it achieves by this behaviour, it is considered purposeful. Without consciousness, however, there must be at least a tendency to achieve actual physical benefit, whether immediate or eventual. There are therefore two senses in which we shall consider a behaviour purposeful. It may either be directed, whether consciously or not, toward achieving a certain benefit, or it may be consciously directed, whether or not the goal is actually beneficial.

1.12 Complex

Not all purposeful behaviour, however, is intelligent. A simple reflex such as closing the eye in response to a puff of air is purposeful, since air blowing toward the eye could be caused by the approach of something harmful, but it cannot be considered intelligent. Comparable conscious behaviour, such as spitting out something that tastes unpleasant, is also excluded. What these lack is *complexity*. To be considered intelligent, a behaviour must be complex.

There are two main kinds of complexity, *sequential complexity*, involving several steps, and *synchronic complexity*, involving several simultaneous criteria. Constructing a burrow or nest is a behaviour performed by many living beings. It is generally sequentially complex in that it involves several steps. An appropriate location must first be chosen, material must be collected and placed correctly, and the work must be evaluated to determine when it has been completed and the behaviour terminated.

When an animal's decision whether or not to eat a certain object is based on consideration of several criteria at once, it is synchronically complex. It is complex even though it involves only a single step. An organism lacking this kind of intelligence would ingest everything it came in contact with. Such behaviour, though purposeful, would not be intelligent. Complexity, then, of one kind or another, is another criterion of intelligence.

There are striking similarities between the complexity of behaviour and other kinds of complexity in nature. The complexity of the pattern of a butterfly's wing resembles that of a spider's web, but one is the product of behaviour and the other is not. The butterfly does not make its wing the way the spider makes its web. The physical development of every living organism is extremely complex and purposeful, but is not behaviour.

Since the criterion of complexity is quantitative, the borderline is unclear. Behaviours consisting of a large number of elements are definitely included, while very simple ones involving only a single element are definitely not.

No mention has been made of *learning*. Indeed, it has been tacitly assumed in the foregoing discussion that behaviour need not be learnt to be considered intelligent. One might prefer to define intelligence differently and exclude any behaviour that is not acquired at least partially by a process of learning. There are indeed some who define intelligence as *capacity to learn*, and it is often used that way in common speech. The problems this would cause are similar to those that would be caused by requiring conscious mediation. It would necessitate excluding even highly complex and purposeful behaviour, such as the spider's web-spinning[1].

Defined this way, as a quality of a behaviour independent of its origin (learnt or not) or how it was produced (conscious or not), it is possible to determine whether or not that behaviour is intelligent solely on the basis of observation and analysis of the behaviour itself, without consideration of the mechanism that produced it. Were consciousness or learning to be included in the definition of intelligence, a problematic ambiguity would be introduced, since there is much behaviour whose origin is not clear. Sometimes it is difficult to determine whether a behaviour is innate or learnt, and sometimes it is indeed impossible. The same behaviour may be innate in one species and learnt in another, so it would have to be

1 It is worthwhile to stop a moment and consider how much is involved in web-spinning. To begin with, no two webs are the same. Each must be tailored to the available branches or other anchors. When making the web, the spider cannot see what has been done already to decide what to do next, because she is standing on the web itself looking horizontally across it. So, although in most ways a spider has no memory at all, it must have the specific kind of memory to remember where the rest of the web is to be able to make the new part appropriately. This does not mean having an internal image of the web, but having mechanisms that accomplish the necessary orientation. It is functional intelligence.

considered intelligent in some cases and not in others. This may even be true of different individuals of a single species, and even of a single individual at different times. Even a single act may involve a complex combination of factors, innate and learnt, conscious and automatic.

However, while being a product of learning is not among the defining properties of intelligent behaviour, the act of learning is itself a form of intelligent behaviour, because learning is complex and purposeful. So the act of learning even a simple behaviour, which itself does not qualify as intelligent, may be considered intelligent by virtue of its complexity. Furthermore, in higher species, learning is an essential part of most intelligent behaviour, because even though the potential for much intelligent behaviour is innately present, it can only be actualized through learning. Learning, as a kind of intelligent behaviour, will be discussed in more detail later.

We have therefore arrived at a definition of intelligent behaviour as that which is purposeful and complex, but not necessarily consciously mediated or learnt. The definition of intelligence is therefore *the ability to perform behaviour that is purposeful and complex, but not necessarily consciously mediated or learnt*. This is for the most part consistent with the general use of the word. Within this broad category are the subsets of intelligent behaviours that are learnt and of those that are under conscious control.

1.2 Ability and Aptitude

At this point it is important to clarify the use of the terms "ability" and "aptitude". If one is not, at the moment, riding a bicycle, but could if he wanted to, then he is said to have the *ability* to ride a bicycle. One who doesn't know how to ride a bicycle but could learn to is said to have the *aptitude* to ride a bicycle. Aptitude is a quality of an individual, a limitation of his potential to develop. Some limitations are obvious. A human being does not have the aptitude to fly because he doesn't have wings. Others, however, cannot be observed or measured directly. Only after attempting to develop an ability and reaching one's limit can one say that he does not have the aptitude to develop further, and even that cannot be said with certainty, since there may be other methods of development that have not been tried. Both aptitude and ability are potentials, but they are of different sorts. When some internal change in the individual himself is required before the act can be performed, and the change can be accomplished by means of learning or development, then he is said to have aptitude but not ability. On the other hand, if it is only a change in the outside world that prevents him from doing it, as, for instance, the lack of an available bicycle, then it is still considered an ability. As for borderline situations, such as one who is asleep or whose leg is broken, it is unimportant for our discussion whether one chooses to consider them abilities or simply aptitudes.

Actual abilities are the products of developmental processes. The physical ability to lift a weight is produced by exercise that develops the muscle. The ability to shoot an arrow and hit a target is developed by practice which develops the nervous system. New abilities can also be produced by combining ones that are already present. A child's ability to read letters later becomes a component of the ability to read words. Other than those few abilities such as crying and moving its limbs that an infant has at birth, most abilities, both physical and cognitive, are achieved through developmental processes involving activity of one sort or another. In the course of maturation new aptitudes are gained, but not abilities. Only by means of activity, such as learning or exercise, are actual abilities ever attained.

The amount of activity necessary to transform aptitude into ability varies. Some students work long and hard to develop abilities that others seem to achieve effortlessly. Even a single individual may find that some abilities come to him more quickly and easily than others. Some words he remembers after hearing them only once, while others he must review over and over. But ability never comes without any activity at all. Even those rare cases, such as musical prodigies, whose ability is attained so rapidly that it seems to be innate, have always had some minimal practice, a combination of the covert activity of listening to music and the overt one of playing a few notes. So, while rapid development is certainly exceptional, like normal development, the process by which it is achieved is active, not passive.

Over and above activity itself, a variety of other factors, especially environmental and motivational ones, also play significant roles in the process of transforming aptitude into ability. Two children may have equal aptitude and practise the same exercises, yet one attains more ability than the other.

Unlike ability, which is easily tested, aptitude is essentially unobservable. This is very problematic, because there are many situations in which it would be useful to know an individual’s aptitude. Unable to evaluate aptitude directly, we must be content with inferring it from ability. Given the complexity of the developmental process, however, this always introduces a degree of imprecision. How satisfactory this method is depends upon its purpose. In its original role as an instrument for predicting success in school, psychometrics can be fairly accurate. The educator is, after all, interested not in the child’s innate potential but in the the practical result of all factors together. If lack of motivation or supportive home environment will, in the end, result in failure to actualise potential, then for his purposes that potential is irrelevant. Ability as a measure of past success is therefore a fairly accurate predictor of the future. If, however, the purpose is to evaluate an individual’s actual potential, other factors must be evaluated and taken into consideration.

Sometimes the word “intelligence” is used to refer to the abilities an individual has already attained, and sometimes it is used to refer to his aptitude. This ambiguity could be avoided by specifying *actual intelligence* or *potential intelligence*, but in practice this is rarely done. It is therefore very important to be aware that these are two essentially different uses of the word “intelligence”, and to be careful not to confuse them. For the purpose of conceptual understanding, however, the former use is the more apt. Since aptitude is defined as potential to attain ability, ability must logically be addressed first. We shall therefore be using that definition throughout, so there will be no further need for clarification.

2. Analysis of Intelligence

Before presenting our analysis, let us take a brief look at some earlier ones. During the first half of the twentieth century, in the search for a theoretical understanding of the biological phenomenon of human intelligence, there evolved two schools. One, whose leading proponent was Charles Spearman[2], maintained the existence of a single factor underlying all intelligence. This factor, which Spearman called “*g*”, was considered to range linearly over individuals, as do physical qualities such as height and weight. Even though in practice it could not be measured as easily as physical traits, by evaluating a variety of activities in which it was manifest, a single-dimensional ranking could be determined, the accuracy of which would depend upon how appropriate the tests were and how well they were constructed. In addition to this general factor, Spearman recognised other independent factors involved in specific areas. By virtue of these factors, individuals whose g-factors are equal nonetheless differ in specific abilities. It is, indeed, the existence of these independent factors that makes measuring *g* itself so difficult.

2. (Spearman, 1923, 1927)

Spearman and his followers went on to elaborate on this basic theory in highly questionable ways, identifying general intelligence as a physical energy within the brain and the independent factors as separate neurological machines powered by it. These speculations notwithstanding, the main part of Spearman's theory is consistent with our informal observations and therefore seems quite reasonable. Some individuals are generally bright, some dull, and most average. Ability in different areas tends to be roughly correlated, even though each may have certain relative strengths and weaknesses. The statistical correlations offered by Spearman and his followers can be seen as scientific confirmation of universal folk wisdom.

It is, however, the blatant exceptions that present a challenge to this theory. Among them autism, and above all the phenomenon of the idiot-savant, figure prominently. If all intelligence is derived from a common factor, how can there exist a human being who is an accomplished pianist yet cannot understand a simple newspaper article or even tie his shoes? Such phenomena are more consistent with the opposing school, best known through the work of L. L. Thurstone[3], which maintained that intelligence is the product of a combination of independent factors which are essentially irreducible to one another. It is therefore not linear but multidimensional, and cannot be represented as a scalar but only as a vector. As for comparing the intelligence of individuals, this means that it is *essentially* impossible to rank them in order of increasing intelligence. By analysing correlations of scores on various tests, Thurstone identified seven factors that he considered to be statistically independent of one another. He referred to them as: S - *spatial* or *visual*, P - *perception*, N - *number*, V - *verbal, ideas and meanings*, W - *words, single words, fluency at dealing with words*, M - *memory*, and I - *induction*. He also identified two more of lesser importance and which were less clearly defined, R - *restriction*, and D - *deduction*.

The modularist theories of the second half of the twentieth century have much in common with factor theories, but were a radical departure from them in their rejection of the relevance of analysing complex intelligent behaviour into elementary factors. The fundamental principle of modularism is that abilities to perform different kinds of tasks such as searching for food, fighting against predators, and interacting with conspecifics, evolved separately by means of the development of separate neurological modules. Elementary factors such as those identified by Thurstone evolved independently in each of those modules, so that the organism ended up with several distinct mechanisms performing the same kind of elementary function, each for a different task. Rather than there being universal elementary mechanisms shared by all areas in which they could be of use, mechanisms were domain-specific, each belonging to a single module. Since each mechanism was part of a specific module and could not be utilised for tasks outside that module, an individual might be able to perform a certain kind of activity well in one area but not in others. Howard Gardner[4], one of the foremost proponents of modularism, identified seven categories whose modules were distinct from one another, 1. *linguistic*, 2. *musical*, 3. *logical-mathematical*, 4. *spatial*, 5. *bodily-kinesthetic*, 6. *interpersonal*, and 7. *intrapersonal.* He referred to these as "intelligences" rather than "factors of intelligence" to emphasize that not only did they serve different kinds of activities, but that they functioned essentially separately from one another.

Other than this basic defining difference, the modularist school also differed from earlier ones in its inclusion of areas that had previously been overlooked, thus broadening the concept of intelligence and correcting the error that had crept in as the concept of intelligence testing expanded from its original purpose of predicting academic success to general evaluation of human abilities. Although other kinds of

3. Thurstone, 1934, 1935
4. Gardner, 1983

intelligence had been tacitly recognised before, this was the first time they were incorporated into a general analysis.

In spite of their differences, however, there are fundamental similarities between all these three approaches to intelligence. 1. All are based on statistical analysis of performance on a variety of tasks. 2. On the basis of that analysis, underlying abilities, whether they are considered global or domain-specific, are inferred. 3. All are concerned with the comparison of individuals. 4. The evaluation of individual abilities is always within the context of overall human intelligence.

In the analysis that follows, we shall be taking a radically different approach. Rather than analysing performance at various activities and identifying common factors by statistical analysis, we shall analyse the concept of intelligence itself and the sort of activities it involves. We shall try to identify the elements of which intelligence is composed and to understand the relationships between them. We are not concerned with evaluating individuals or ranking them in any way. Our interest in individuals and the differences between them is limited to what they reveal about the nature of intelligence and the mechanisms by which it is performed. In that it is a rejection of modularism and a confirmation of the global nature of mental abilities, it is a return to factor analysis. Due, however, to the fundamentally different approach, the analysis that emerges is very different from earlier factor theories.

3. Independence of Function and Mechanism

As in other aspects of biology, a particular function may be performed by more than one mechanism. Hair, scales and feathers all protect the body; exoskeletons and endoskeletons both provide support. A monkey can achieve the goal of grasping a branch with either its hands, its feet or its tail. The immune system comprises many parts, all of which perform the function of protecting the body from infection. Conversely, a single mechanism can perform more than one function. The mouth eats, breathes and talks; the hands grab, feel and move things. And when there are several mechanisms performing the same function, some may perform other functions as well. Of the many mechanisms that protect the body, hair and feathers also help maintain body temperature but scales do not; exoskeletons also provide protection; some bones produce red corpuscles.

Such relationships exist outside of the biological world as well. Some tools, such as pens, pencils and brushes, can be used for both writing and drawing. These are essentially different functions, one involving symbolisation, the other representation. There are other tools that are good for only one. Keyboards and rubber stamps can be used for writing but not drawing. Rulers and compasses can be used for drawing but not writing. Moreover, some of these tools can also be used for other purposes, such as solving mathematical problems.

So too, there are cognitive mechanisms that serve more than one category of intelligence, and a single kind of intelligence may be performed by several different cognitive mechanisms. Of various mechanisms that perform the same function, some may work in similar ways, and others, though they accomplish similar goals, may do them differently. Some may be more efficient than others, some more powerful. Some may be better in one way, others in another. A brush cannot make as small letters as a pen or pencil, but is better for making large ones. Different mechanisms may be used by different species, by different individuals within a species, or even by a single individual in different situations. One mechanism may perform it more quickly than another but less accurately. Thus when you need to add two numbers quickly but need only a rough estimate you do it one way, and when you need a precise sum but are not in a hurry, another way. In reading English, unfamiliar words are read phonetically, while familiar ones are read by recognising the word as a single unit. In short, there is no direct correspondence between cognitive mechanisms and the functions that are achieved.

4. Taxonomy of Intelligence

In later chapters we shall present some hypotheses concerning various mechanisms, but here we are directing our attention only to functions. We shall begin by constructing a taxonomy of intelligence intended to cover all the kinds of intelligent behaviour performed by humans and other living beings. Our construction will be hierarchical in that it will begin with the most fundamental and general aspects of intelligent behaviour and proceed to increasingly specific ones.

4.1 Class I - Spatial and Temporal Intelligence

Among the most basic components of intelligence are two broad categories whose function is the interpretation of sensations for the perception of the environment and for the control of actions so that they will be appropriate for its current state. They are therefore involved in both perception and action, both of which are within our broad definition of behaviour. These are the categories of *spatial* and *temporal* intelligence. They are shared in varying degrees by humans and other animals. While there are other aspects of perception that cannot be considered intelligence because they are too simple, these are complex because they take multiple sensations and organize them in meaningful ways.

4.11 - Temporal Intelligence

Temporal intelligence includes ability to recognise sequences and patterns of events. Sensitivity to rhythm and melody, for instance, involves recognition of patterns of sounds. Some patterns, such as hearing a certain sound, then a different one, and then the first again, involve only the order of the sounds, not their duration. The elements of such patterns may be simple, such as notes of varying volume or pitch which can be recognised without temporal intelligence, or complex, such as combinations of notes or notes of different durations. In the former case recognition of individual elements is not considered intelligence, but recognition of the pattern is. In the latter, even recognition of individual elements requires intelligence. Recognition of notes of equal pitch and volume but of varying duration requires temporal intelligence even when they do not form any pattern. Music typically involves a combination of pitch, volume, order, and both absolute and relative duration, both of the sounds themselves and of the pauses between them. Temporal intelligence is also involved in control of behaviour, such as when or how rapidly an action is performed. Thus it may involve perception, behaviour or both.

The arrangement of sensations dealt with by this kind of intelligence is linear, that is, single dimensional. Though sound is one of the most obvious sensations processed temporally, temporal intelligence applies to other sensations as well. It is necessary in interpreting motion of any kind, such as movement of animals, leaves blown by the wind, water flowing, and other kinds of change. This kind of intelligence underlies music, spoken language, social interaction, and coordination with the motion of other humans, animals, and inanimate objects that move. In higher cognitive development, it is ultimately also the foundation for the development of such abstract concepts as *change*, *causality*, and *volition*.

4.12 - Spatial Intelligence

Spatial intelligence involves recognition of relationships between sensations experienced simultaneously. It need not involve forming the concept of a space filled with objects. The much simpler ability to appreciate the relative position of one sensation to another, such as “above”, “below”, “inside” or “outside”, “close” or “far” is also a kind of spatial intelligence. It may involve position of an object relative to the observer or of one object or sensation to another. Unlike temporal intelligence, which arranges sensations in a single dimension, spatial intelligence may involve two or three dimensions.

For human beings, most of the information processed by spatial intelligence is derived from vision. But as temporal intelligence is not limited to sound, spatial intelligence can involve senses other than sight. Touch is the second most important, especially for those who are blind but also for those who have sight when they are in situations in which vision is not available, as when moving in darkness or when examining areas that are not visible. For some species, however, spatial intelligence is used to process other senses. Bats apply it to sound, snakes to a sense akin to taste and smell via chemical receptors in the tongue, and pit vipers to temperature. All of these sensations give them information about their surroundings, and their interpretation of those sensations to direct their behaviour constitutes spacial intelligence.

The input processed by spatial intelligence need not be simultaneous. Sensations may be experienced at different times and gradually pieced together. When a blind person forms an idea of the shape of an object by moving his hand across it and feeling it from different sides, the input is sequential, but this is spacial, not temporal intelligence. Indeed, information derived from sight is not always simultaneous either. A seeing person may also look at an object from different directions and may look at different parts of it separately to form an image of it. In doing so, both sensations and motions are processed, so that the result is independent of the time spent viewing the different parts or the order in which they were viewed.

In higher animals, these two kinds of intelligence underlie the concepts of *time* and *space*. However, much more basic than these abstract concepts are the abilities to function in the environment that depend upon organising it these ways. Indeed, these concepts are artefacts imposed upon experience. They are theories, in the sense described earlier. Like other such theories, they are not arbitrary. They represent actual relationships in the world that are being experienced. The application of the labels “time” and “space” and the convention in Western Culture of representing time spatially by a one-dimensional array of points on a line tend to obscure the essential difference between them. Time is not really comparable to the dimensions of space. It is not an extended continuum within which a being has freedom to move, but a sequence of events, each of which happens and is then over and replaced by another. The mental mechanisms by which temporal and spatial interpretations are performed are also essentially different from one another.

4.13 Orientation

Orientation is the ability to behave appropriately for one’s place and time. For lower animals it is entirely functional. An animal has a variety of behaviours of which it is capable, yet the one it performs is the one that is beneficial under the circumstances. A cat pounces on the spot where its prey is standing, not to the left, not to the right, not too close and not too far. A bird begins to fly south as winter approaches and back north in springtime. For human beings, orientation also includes conscious recognition, as well as abstract concepts such as one's age or how far one has to go to get to a destination.

4.14 Agility

For those animals capable of complex motions, the ability to control one's body is also a kind of intelligence. For human beings, the activities performed by the hands constitute a special category of human behaviour, so the intelligence involved in controlling them is given a special name, *dexterity*. That of the body as a whole is called *agility*. There are comparable kinds of intelligence in the control of the voice and other separate organs which do not have separate names.

4.2 Class II - Interaction with the Environment

After these come four categories that involve interaction with the environment. They are *recognition*, *learning*, *concrete reasoning* and *coordination*.

4.21 Recognition

The essence of *recognition* is the ability to respond differently to different experiences. For higher creatures, it generally involves a feeling of familiarity when experiencing something that had been experienced in the past. This kind of recognition is derived from a process of learning. But there is recognition in which neither the response nor the experience that evokes it is learnt. It is the ability to recognise certain experiences and distinguish between them that underlies the selective application of innate responses, as when bees recognise certain colours of flowers or when birds recognise a danger cry.

There are many different kinds of things that can be recognised. They range in complexity from simple sensations such as colours or pitches to highly complex ones, such as the style of a composer or the form of a differential equation. However, even the ability to recognise simple things is sufficiently complex and purposeful to be considered intelligence, because the act of recognition involves distinguishing between different stimuli perceived by the same sense. The act is complex even when the thing recognised is simple. It is not like the reflex reaction to a tap on the knee or a puff of air at the eye which are not intelligent behaviour.

Some recognition involves reference to a symbol, as when one recognises a colour as orange or a shape as a square. But recognition does require symbols. Animals learn to recognise colours even though they do not have names for them. Even recognition of complex patterns by human beings need not involve symbols. A person can recognise something without having a name for it and without being able to describe it or identify by which features he recognises it.

At some fundamental level, the ability to recognise must be innate. The recognition itself need not be innate as it is in bees, but there must, at the very least, be an innate ability to perceive an elementary quality. Though this ability to perceive is a property of the nervous system which is in itself simple and therefore not intelligence, it is a necessary basis for the ability to distinguish and therefore to recognise.

In addition to perceiving and distinguishing, recognition must include directing behaviour on the basis of that perception and distinction. The complexity involved is in the choosing of one behaviour over another. An insect's recognition of a colour or odour differs from the closing of the eye in response to a puff of air in that there is more than one sensation to which the organ is sensitive, some of which evoke a certain behaviour and some of which do not. The choice need not be large. Even if there are only two stimuli and two behaviours, or even a single behaviour which may or may not be performed, the organism must be able to distinguish one sensation from another so that it can respond with the appropriate behaviour. Here again, although the paradigms of recognition in human beings involve conscious thought, that is not necessary. Recognition is intelligent behaviour even when it is only functional.

4.22 Learning

There are various kinds of processes that modify future behaviour. Some are physical. They include development of the nervous system, increase in body size or muscle strength, gain or loss of limbs, and maturation or deterioration of organs. All of these are internal processes that affect which behaviours an organism is able to perform. Future behaviour can also be modified by physical changes in which ability is not changed, such as the emergence of innate behaviours in the course of maturation. When an animal begins to exhibit adult sexual behaviour it has not necessarily acquired any new abilities, but acts differently. Another source of modification of future behaviour is through external factors such as injury, drugs, nutrition and other chemical agents. All of these can physically alter an organism in ways that effect its future behaviour.

But there is another way by which future behaviour can be modified which is radically different. That is *learning*. It differs in that it involves *active participation* of the organism, and that activity is always some kind of *interaction*. The interaction is generally with something external, as when an infant learns that moving its arms and legs makes the toys hanging in its crib move. Sometimes, however, the interaction is between different parts of the organism itself, as when the infant learns that biting its own finger causes pain, or when, through repetition of a certain movement, it becomes more skilled at it. Activity is an essential condition of learning. The organism cannot be passive, it must be active. It performs some action, and as a result of that performance the neurological structure of the organism is modified in such a way that it behaves differently in the future. Thus we shall define learning as *modification of future behaviour by means of either interaction with something outside the organism itself or physical interaction between parts of the organism*. The term "interaction" in this definition is to be understood in its literal sense as involving action on the part of the organism.

This definition of learning has much in common with the description of the transformation of aptitude to ability presented earlier. There are, however, certain significant differences that must be pointed out. First, the product of learning is not always ability. Through interaction with something an organism can also modify existing dispositions or acquire new ones, such as becoming attracted to it or afraid of it. Second, while transformation of aptitude to ability always involves some kind of activity, it need not be an interaction. Soon we shall be discussing reasoning. Some reasoning is entirely internal, so it cannot be considered learning. Yet by reasoning too, aptitudes can be transformed into abilities. Learning is therefore a process that can, but need not, transform aptitudes to abilities, and when it does, it is only one of the possible means by which that transformation can be accomplished.

Learning therefore has the special quality of being *behaviour that affects behaviour*. The ability to learn makes behaviour flexible rather than fixed. This flexibility is generally characterized by the acquisition of the new *abilities*, but sometimes it is not a new ability but a new *disposition.*

The new behaviour need not be purposeful or complex. By learning, a person can acquire the ability to cross his eyes or develop the habit of drumming his fingers on the table. Thus the *product* of learning may or may not be the kind of behaviour that satisfies the criteria of intelligence, but the *act* of learning is in all cases intelligent behaviour, because the act itself is always complex, and, by definition, always tends toward the goal of modification of future behaviour.

The new behaviour may also be either *overt* or *internal*. The products of learning can be skills such as riding a bicycle, playing a violin, or solving equations, they can be knowledge, such as the names of the countries of Europe, or they can be understanding, such as why ships float but rocks sink. Here, the problem of including these as behaviour is similar to that encountered in defining intelligence. Though what is acquired seems to be passive knowledge, these too are really abilities to perform new behaviours. In some cases, as in learning a passage by heart, it is the ability to recite it or recognize certain phrases from it. In learning a fact, however, it is more than just the ability to answer questions. It is, rather, that by adding this fact to the entirety of the learner's body of knowledge he becomes able to use it in reasoning in conjunction with other facts.

The product of learning, the new ability acquired, is not always realised immediately. Sometimes the opportunity to perform it simply does not arise. In other cases, acquisition of the ability is impossible due to lack of physical maturation, but upon completion of that physical development the ability immediately appears. A child, for example, may have learnt certain chords, but cannot play them on the piano because his fingers aren't yet long enough. When they grow, he is immediately able. The learning took place earlier and its result became actualised when the necessary physical element was supplied. Everything necessary for the ability was present at the time of learning except for a certain physical element, and once that was supplied the ability emerged. All learning therefore involves both *aptitude* and *development*. Aptitude generally precedes development, but development can sometimes proceed in the absence of aptitude, the actual behaviour only appearing after the aptitude has been attained.

4.23 Concrete Reasoning

Reasoning, like learning, involves modification of behaviour, but differs in two ways. First, the effect of reasoning can be limited to the present without having any effect on the future. When one adds a column of numbers, reasoning determines what sum he will write at the bottom, but his future behaviour is not appreciably modified. Similarly, a person uses reasoning to tell where to put a piece in a jigsaw puzzle, but it has no effect on what he does in the future. Learning, on the other hand, may or may not involve modification of current behaviour, but must modify future behaviour.

Secondly, reasoning involves creating a new behaviour or selecting from among known ones, whereas learning can consist simply of following an existing pattern of action. Being trained in a certain behaviour, either by the intentional act of another living being or simply by circumstances, constitutes learning, even though it does not involve any choice on the part of the learner. He does not choose to follow, he is forced to, but in the process he learns. His active involvement consists of moving his limbs in the way he is being forced to, and the result is his improved ability and stronger inclination to move them that way in the future. Not so reasoning. He must at least initiate some kind of choice himself.

The sort of reasoning that belongs to this second level of intelligence does not involve the use of symbols. Objects involved are all present, available to perception by the sense organs. This is referred to as "concrete reasoning". It is characterised by utilising relationships between elements of the environment. A gardener uses concrete reasoning when he moves his shovel to avoid a rock, or looks at the tree he wants to plant to decide how deep to dig the hole. A dog uses concrete reasoning when the rabbit it is chasing runs through a hole in a fence, and the dog, after trying to go through the hole and finding it too small, goes around the end of the fence. But not all concrete reasoning is simple or primitive. Some is highly complex. A mechanic uses concrete reasoning when he repairs a machine, and even an inventor who takes existing parts and constructs a machine that is different from any before is using concrete reasoning. Even games such as checkers or chess or mathematical computations done on paper can, to a certain extent, be performed by concrete reasoning.

Piaget's theory of cognitive development explains how this kind of reasoning is gained by the child considerably before abstract reasoning, which belongs to the next level of intelligence. Here, however, we are not concerned with the processes by which they are acquired by the individual. We are separating them because they involve different degrees of complexity of cognition itself. Both involve recognition of properties and relationships, but in concrete reasoning the things having these properties and between which these relationships obtain are all present, whereas in abstract reasoning some are not. In the following chapter we shall discuss learning and reasoning in more detail.

Although reasoning is internal and cannot be observed directly, it can be inferred from certain aspects of observable behaviour. One is the absence of false attempts. When a human being or an animal tries to do something without reasoning, its actions are random. If it goes directly to the solution or approaches it by a sequence of better and better attempts, its actions must be guided by some internal process. When an ape puts two sticks together to reach a banana, it demonstrates concrete reasoning.

4.24 Coordination

Another broad category of intelligence is *coordination*. This is the ability to adjust one's own behaviour to that of another being, to a natural phenomenon, or to any other change in the environment, as people do when singing or playing instruments together. One of the simplest forms of coordination is *imitation*. One individual coordinates himself with another by doing the same thing the other does. The model is usually the same sort of being as the imitator itself, but not always. Humans can also imitate the rhythmic singing of insects or the motion of a machine. Generally, only select aspects of the action are imitated. For example, if the model makes two sounds and then pauses, two sounds and then pauses, the imitator might reproduce the same pattern but using different sounds. He might reproduce the pattern but change the speed, and might even reproduce it by some other sort of action, such as clapping, dancing or waving hands while someone else sings or plays an instrument. Even when the same sound is used, the way it is produced might not be the same, as when a human being imitates the chirping of a cricket.

Beyond imitation, coordination can involve *anticipation* of coming action. When this is done, it is possible to perform the same action as the model at the same time even though the model is varying his own actions and not just repeating the same thing over and over again.

After that there is more complex coordination, in which the actions of one individual are not exactly the same as those of the other. This is the kind of coordination involved in many sports and children's games, in singing rounds and harmony, and in having a conversation with other people.

Coordination may be used for cooperation, as when birds sing or fly together, but it is also used in competition and conflict, as when a bird swoops down on its prey. It can also involve coordinating with inanimate objects or changes in the surroundings, as in adjusting one's behaviour to the length of the day.

The mechanisms by which coordination is accomplished vary as do the mechanisms of the other kinds of intelligence we discussed above. The ability to imitate or anticipate another's actions may or may not involve imagining those actions. Anticipation can be accomplished without such imagination, by simply recognising certain actions and responding to them in certain ways. Thus when a predator strikes at a moving target, it need not be imagining its prey in the future location, but simply adjusting its own motion to the prey's current direction and speed.

Adjusting one's behaviour to the current time and place, such as not taking one's clothing off in public, speaking softly in the theatre, or not making jokes when one hears sad news, can also be seen as a form of coordination, although not a very demanding one, since it does not require moment by moment response.

4.241 Communication

One special kind of coordination is *communication*. Although the paradigm of communication is language, it is important to recognise that the two are distinct. Communication can be accomplished without language, and indeed without the use of any symbols at all, and language can be used for purposes other than communication. The essential quality of communication is that there is an *intention to elicit the coordination* of another being. When it is successful, the two coordinate with one another. It requires recognition of the intelligence of the other, of its capacity to coordinate. This recognition need not be conscious or conceptual. Functional recognition is sufficient. Thus the coordinated behaviour of an infant and its caregiver or of a dog and its owner are communication. However, exchanges such as mating calls of lower animals or of insects, where neither is the sound produced with the intention of communicating with another nor is the response made with awareness of the significance of the sound, are not. Though these certainly involve coordination, it is only in the eyes of the human observer that there seems to be communication.

It is clear that all four categories of Class II, *recognition*, *learning*, *concrete reasoning* and *coordination*, make use of and are dependent upon the categories of Class I.

4.3 Class III - Creative Intelligence

Related to these is the class of *creative intelligence*. This kind of intelligence may or may not involve adaptation and solving immediate problems. Even when it is not, it is nonetheless goal oriented because it is ultimately beneficial, the products of creativity being useful afterwards for adaptive behaviour. The factor that distinguishes creative intelligence from the four in Class II is that it is derived internally rather than externally.

4.31 Originality

The two most important kinds of creativity are *originality* and *balance*. *Originality* is the ability to spontaneously produce new kinds of cognition and behaviour which are not reproductions of any model, neither one that is currently present nor one that was witnessed in the past. The term "originality" is generally used to refer to human behaviour involving reasoning and conscious control. We shall define it more broadly to include innate behaviours such as web spinning, which are evoked internally rather than in response to an external stimulus. The defining quality of originality is that the *origin* of the behaviour is internal, not derived from something outside the organism. Within this, the uniquely human kind of originality where new behaviour patterns such as inventions, strategies, melodies and designs that were not innately determined are created, is an important subcategory[5]. Above all, the combination of words to form sentences that were never heard before, and of thoughts to form new ideas, are kinds of originality that are central to the human way of life. Original utterances are found not only in poetry and fiction, but in everyday speech as well. There is no behaviour that offers greater freedom and flexibility, and therefore opportunity for originality, than language.

But even language does not always involve originality. Much of speech is repetition of sentences or phrases heard previously, or combination of previously heard phrases according to previously learnt patterns. True propositions too, in that they are reflections of reality and therefore externally derived, are not original behaviour.

Originality, like learning and reasoning, is a source of endless new behaviours. In those animals that are capable of learning, it can also be a source of modification of future behaviour, if the new behaviour is repeated and then incorporated into the individual's repertoire.

4.32 Balance

The second, *balance*, is the ability to coordinate one's own actions with one another. It is by this ability that a being's actions can be graceful and harmonious. This is often referred to as "coordination". However, since we are using the term "coordination" to refer to coordination with things that are external, we have chosen to refer to it as "balance" instead. Neither term captures all facets of this ability. It also includes the ability to produce rhythmic behaviour, repeated patterns and symmetry. It makes possible the production of a balanced artefact such as a nest, a web, a painting, a poem, or a melody. Although external factors may be involved in motivating the behaviour and in directing its form, this aspect of its form is derived not from without but from within. Thus a bird makes its nest to fit the branches to which it is attached, but the shape and size are determined internally.

4.4 Class IV - Abstraction

Beyond these there is another elementary kind of intelligence which is particularly characteristic of the behaviour of higher animals, where it contributes especially to the categories of learning and reasoning, but which is found to a lesser degree in lower animals as well. It involves *abstracting* individual aspects from the totality of experience. By virtue of this ability, a being recognises qualities or relationships that are never experienced alone. There are four main divisions within this class, *integration*, *abstracting qualities*, *forming rules* and *recognising relationships*.

4.41 Integration

5. Even this paradigm originality is never entirely novel. Like the innate originality of the spider, it rests on a foundation of preexisting behaviours, and the modification and recombination of these is also, for the most part, guided by preexisting rules and patterns.

Integration is the combination of sensations into compound units. Without the ability to integrate experience there are no objects, only sensations. This is the way lower animals experience the world. When a worm comes up against a stone and turns to the side, it has no thought of an object or of its own motion around it. There is only the feeling of hardness, the inability to go straight and the response of turning. Earlier, we described the integration of sensations into objects and other unifying entities as “theories” because they are never observed but only imagined to account for observed phenomena. We briefly discussed the question of whether human beings are innately provided with these theories or whether each individual creates them himself in the course of interaction with his surroundings. Here, however, this question will not be relevant to our discussion, because we are concerned only with abilities regardless of their origin. Furthermore, integration need not be conceptual. Even if an animal has the functional ability to utilise unifying entities to conduct itself in its environment rather than using only disconnected sensations, it has this kind of intelligence. These are simply ways of thinking, of processing the information given by the nervous system. It would not be appropriate to apply the term “theory” to them, but they are certainly integration.

4.42 Abstracting Qualities

Next to integration, *abstraction* is a fundamental and pervasive part of human thought. When we say that the ball is large, red and round, we are abstracting. There is no redness or roundness independent of the ball. Abstraction enables us not only to see two objects as similar, but to identify the similarity. A ball and a melon are very different from one another, but they have the common quality of being round. Language sometimes confuses us and misleads us into failing to recognise the act of abstraction. When an abstracted quality is referred to by a noun rather than an adjective, we are misled to think of it as an object. Thus numbers and shapes are abstractions. There can be a square piece of paper or wood, or of lines of chalk, but never just a square.

The ability to abstract qualities presupposes some kind of integration which is now modified. Recognising the qualities of an object and abstracting them, separating them from the object itself, is not a reversal or a nullification of the integration and a return to primitive disconnected sensations, but on the contrary, a new and more complex perception of sensations. They are now seen in the context of objects. Without integration and abstraction there is just *redness*. With them there is an apple, and it is a *red* apple.

There are certain kinds of lower behaviour that appear to involve abstraction but really do not. In some, an animal does not recognise the various objects as distinct from one another but thinks they are all the same one. Having failed to recognise the difference between them it treats them all the same, and if a new object is encountered it is treated like the old ones. There is also another even lower phenomenon that superficially resembles abstraction but is really just conditioned behaviour. The property, such as colour, is not seen as a property of an object but only as a sensation. If a response is learnt, it is to the sensation, not to objects having a certain property. We can therefore characterise abstraction as *the act of seeing similarities between things while recognising that they are distinct*.

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4.421 Classification

The foundation of classification is the ability to perceive similarities and thereby to *classify*, to put things into groups of similar objects. Classification makes possible generalisations and thereby common nouns.

Experience presents one with individuals, “John”, “Pete” and “Harry”, but never “man”. The common noun must be constructed by classifying the individuals that have been experienced on the basis of the qualities common to all of them.

Like the other kinds of intelligent behaviour we have discussed, abstraction and classification need only be functional, not conceptual. It is not necessary to have a name for the class, but only to identify new individuals who share the defining qualities and treat them as those already known would be. Animals such as dogs seem capable of this sort of functional classification, and this seems to be the nature of classification in human infants during their early months.

4.422 Recognition of Properties

After the ability to classify comes the ability to *recognise properties*. When an animal learns that fruit of a certain colour is sweet and that of a different colour is bitter, and from then on selects fruit on the basis of colour, it is abstracting an isolated property of the object from the integrated totality of the object that it is experiencing and *attaching significance*, albeit only functional and not conceptual, to that property.

4.423 Second-Order Abstractions

Beyond abstraction of qualities of objects are abstractions of qualities of abstractions, which are called “second-order abstractions”. Thus *red* and *green*, *large* and *small*, are abstractions from concrete objects, whereas *colour* and *size* are second-order abstractions. Concepts such as *time*, *space*, and *causality* are also abstractions. This sort of abstraction too can sometimes seem to be involved in the behaviour of infants and lower animals. Behaviour that, when performed by a human being, indicates grasp of concepts such as object permanence and identity may in a lower animal be derived from innate behaviour patterns. When a fly flies away from a hand that is raised to hit it, it has neither the conceptual awareness that its life is in danger, nor even the minimal concrete reasoning of avoiding something that is attacking it.

4.424 Abstraction and Originality

Some abstractions involve originality but others do not. Abstractions such as colours are properties of the physical objects themselves or of the subject’s experience of those objects. The act of abstraction involves only recognising the similarity between them while distinguishing them from one another. However, abstract concepts such as *energy*, *momentum*, and *consciousness* are theories that go beyond experience itself, so they involve innovation on the part of the observer. He must imagine an entity that he has not experienced, that is not given to him directly by his senses.

4.43 Forming Rules

Closely related to abstraction is the act of *inference, forming general rules* from particular instances, as when a child discovers that wood floats and stones sink. Whereas a quality is a generalisation over individuals (an apple, a bird and a flower all have the quality “red”), a rule is a generalisation over instances. The bell is struck once and there is a sound, twice and there is a sound, three times and there is a sound. By inference, one derives the rule that striking the bell is followed by a sound.

Here too, there are lower levels of intelligence that are superficially similar. When a cow discovers that leaning against an electric fence is painful but leaning against a tree is not, it has not formed a rule. To be considered a rule, there must be recognition of distinction between instances and generalisation over them. Other behaviour of cows indicates that they are incapable of such reasoning, but have simply learnt by experience not to lean on electric fences. Furthermore, the qualities by which the cow recognises the fence are only separate sensations, not qualities seen within the context of an entity.

The close relationship between qualities and rules is reflected in the relationship between the logics of set inclusion and propositional calculus.

4.44 Recognising Relationships

Akin to the ability to abstract qualities is the ability to *recognise relationships*. As with qualities, relationships vary greatly in degree of complexity. They can be as simple as the physical relationships of “above” and “below”, or as complex as laws of motion and other laws of physics or the legal and social relationships of property ownership and social obligations. Although there is in principle no limit to how many elements are involved or how complex the relationship may be, every individual is limited in the degree of complexity that he can grasp.

As qualities are typically expressed by adjectives, basic relationships are expressed by prepositions. In neither case, however, is language necessary. To have the concept “on” does not require knowing a word but seeing the similarity between the cat being on the mat and the bread being on the table. Even using the relationship functionally involves this sort of intelligence. When an infant who already knows that a toy lying on a blanket can be brought closer by pulling the blanket, does the same thing with a toy that is on a pillow, it has begun to grasp the concept “on”.

The ability to recognise relationships is the foundation of the ability to connect two experiences that always occur together, either simultaneously or in close succession. When infants notice a relationship between the proprioceptive sensations of moving their hands, and the changes in the visual field, they begin to gaze at their hands while moving them in front of their faces. Their later behaviour indicates that this is the beginning of true recognition of relationship and not simply a behaviour pattern they find enjoyable. From this, they eventually develop the concept of a body and of a self as separate from other things in the world.

4.5 Class V - Symbolic Intelligence

Beyond these categories is one that is almost unique to human beings, being shared only with the highest animals, and then only to a limited degree. That is *symbolic intelligence*, the use of symbols in place of elements of current experience. Using symbols in place of single concrete objects makes it possible to reason about an object even when it is not present. This is not the same as imagining the object, which does not require a symbol. More important than representing individual objects, however, symbols can be used for generalisations, for collections and for abstract concepts. It is especially with respect to abstraction that the use of symbols increases the power of other kinds of intelligence many fold, because it makes it possible to identify and manipulate abstract concepts. The power of symbolic reasoning is therefore in its combination with other of the above abilities, especially *learning* and *abstraction*.

4.51 Abstract Reasoning

Besides making it possible to reason about things that are not currently present and about collections, types and properties, symbols make it possible to perform more complex kinds of reasoning. By representing relationships and reasoning processes themselves by symbols, it becomes possible to incorporate them into further reasoning. Thus symbolic intelligence is combined with the logic of concrete reasoning to produce *abstract reasoning*, in which reasoning, recognising relationships, and inferring logical implications is no longer limited to currently present physical objects, but can be applied as well to properties, relationships and other concepts. Abstract reasoning might also be called *symbolic* or *mathematical* reasoning. What is customarily called “mathematics” is only a portion of this broader category. In mathematics, the process of abstraction has become complete, in that only forms are considered, without regard to the material of which they are composed. Thus traditional algebra deals with number and quantification, geometry deals with shape, and topology deals with spatial relationships. So too, propositional and predicate calculus and other kinds of logic deal with truth relationships.

Between concrete reasoning and the completely abstract reasoning of mathematics lie various kinds of reasoning that make use of both in varying degrees. Physics is very close to mathematics in that it involves a high degree of abstraction, but in physics some of the abstract concepts, such as those of a physical object or of motion, are bound to properties of actual physical objects rather than being defined freely and formally as in mathematics. The kind of intelligence involved in mathematics, however, is essentially the same as in other kinds of abstract reasoning, and mathematical ability is not essentially different from the ability to perform any other kind of abstract reasoning.

There are many kinds of intelligent behaviour in which abstract reasoning is helpful but not necessary, because they can be performed in more than one way, some of which involve abstract reasoning and others not. Individuals who have strong ability in abstract reasoning will tend to apply it in these areas, while those who do not will do them in other ways. Musical ability, for instance, is often found in those with strong mathematical ability, but is also found in those whose mathematical ability is weak. The former generally have an understanding of the musical structure that the latter lack. A mathematician notices certain kinds of complex relationships in the music he is playing or listening to, even if he is not explicitly analysing it. One who lacks this kind of abstract reasoning ability may be able to enjoy and perform the same music by processing it concretely. Certain tasks require abstract intelligence in certain circumstances but not in others. An artillerist must use mathematics to aim his cannon and hit the target, but a hunter can aim his gun without any such knowledge. It can sometimes even be accomplished by innate behaviour. An archerfish hits its prey without reasoning or training. This is certainly a kind of intelligence, but it is in the category of coordination, not reasoning.

4.52 Propositions

Symbols also greatly enhance communication, making it a way of sharing knowledge. By combining symbols it is possible to form *propositions* corresponding to events or to other physical or abstract relationships. Although verbal statements are the paradigm of propositions, words are not the only kind of symbol of which propositions can be composed. The picture of skull on a bottle of poison is a proposition too. Even when a proposition is expressed by a verbal statement, the proposition is not the statement itself, but what it symbolises. Knowing the words themselves without understanding them does not, therefore, constitute knowledge of the proposition. On the other hand, knowing the proposition does not require knowing a verbal statement of it. Knowing the proposition, "Dogs have an average lifespan of ten years" does not mean knowing the words, but being able to answer questions such as "About how long do dogs generally live?" or, "Do dogs generally live more than twelve years?" Indeed, one can know a proposition without it ever having actually been stated. *Propositional knowledge* can therefore be derived from various sources. It can come from hearing and comprehending a statement of the proposition, or from experiencing and then forming a proposition on the basis of experience.

Thus, propositional knowledge is a kind of knowledge made possible by the existence of propositions, even though the specific knowledge contained in a proposition need not have ever been expressed in a statement of any kind. It is knowledge *about* things, which is unlike the direct knowledge derived from experiencing them or reasoning about them.

Each of these kinds of knowledge, direct and propositional, has certain advantages over the other. Direct knowledge is richer in that it includes many aspects of the thing known. Someone who has walked through a forest and seen the many kinds of plants and animals there knows much more about it than one who has heard a description of it. However, propositional knowledge enhances cognition in two important ways. The first is to increases the amount of knowledge available to an individual. Without propositions all knowledge must be derived from experience or reasoning. With them, knowledge can be shared with others who have no direct access to it. Each one is thereby able to amass a large body of knowledge of things that he has never experienced. The second is as a tool for abstract reasoning. Here, the weakness of propositional knowledge becomes its strength. The proposition contains much less knowledge than that derived from direct experience, but what it does contain is clearly defined and identified, so it is easier to manipulate. Furthermore, without propositions, abstract reasoning is generally limited to simple inferences. Symbols are the first step toward more complex reasoning, and their combination to form propositions the second. Together, they provide more powerful ways to grasp and store knowledge, and new and more complex ways to combine inferences.

Although the ability to form propositions is based on the ability to comprehend abstraction, the information contained in the proposition itself need not be abstract. Most propositions used in everyday life represent concrete events and relationships, not abstract concepts. Use of symbols in general, therefore, and propositional intelligence in particular, require only minimal abstract reasoning.

The effect of propositional intelligence is not, however, entirely positive. Since a proposition is not a fact itself but the description of a fact, it is also possible to form propositions that do not correspond to any facts at all. Just as it is possible to form true propositions such as that gold is softer than iron or that Paris is the capital of France, it is also possible to form false ones, such as that heavy things fall faster than light ones. Thus it also makes *lies* possible. While a limited degree of deception is possible with non-symbolic communication, it is greatly increased by the introduction of symbols. And even without intentional deception, the possibility of error is increased by the ability to imagine false propositions.

5. Some Concluding Remarks about the Concept of Intelligence and Some Words of Caution

These twelve kinds of intelligence, *spatial, temporal, recognition, learning, concrete reasoning, coordination, originality, balance, abstraction, symbol, abstract reasoning,* and *proposition* are called "fundamental" because they underlie all intelligent behaviour. Finer and more subtle divisions could certainly be made, but these will suffice.

A final word of caution before we move on to analysing the mechanisms of intelligence. The use of nouns such as “intelligence” and “ability” is misleading in that they imply the existence of entities, of “things” that they are describing. Like many other nouns in English and similar languages, these are not physical things, nor even specific qualities like height or weight, but descriptions of an individual, something about him, not something that he “has”. An adjective would be more appropriate. Indeed, the most accurate would be a verb. Thus rather than saying that one has strong intelligence or ability in certain areas, it would be better to say that he acquires information or sees relationships easily, or coordinates his behaviour with his environment. Since in the following chapters we shall continue to follow the usual linguistic conventions, it is important not to lose sight of their real meaning.

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for interest to promote/enhance/ memory, it is not enough to be interest in the object. giving maths examples about pizzas does not help, even though the student is interested in pizzas - he is only interested in eating pizzas, not in counting them - so it is no better than giving them in terms of stones. the example must involve an action, something he is interested in doing, for instance, that he likes to do. maths must be directly involved in the action itself. perhaps it is indeed that the maths must be part of the schema, and be assimilated into it. it may indeed be that for a student to understand and remember maths, the numbers themselves must be important for him, in which case no amount to tangential motivation would help