CHAPTER 7

A GENERAL OVERALL VIEW OF THIS STUDY

Player Voiced Aerophones as a Type

PVAs have been used in the past in a wide variety of forms, for a wide variety of uses. In this study they have been seen as an extension of the human voice, i.e. developing via the megaphone to the PVA proper. Thus, one expects to find a spectrum of forms spanning this range as, indeed, is found in antiquity. The name proposed in this study, player voiced aerophones, recognises this intimate connection with the human voice and, frequently, with other parts of the vocal apparatus. As discussed in Chapter I, the term "Brass instruments" serves well as a commonly used name for the group and its restricted range of usage is generally understood.

Along this continuum of instruments, one clearly identifiable form exists, that of the variable tone-colour instruments which includes the modern didjeridu. Unfortunately, our separation from instruments of this type is effected by our organocentric view of "high development". An instrument developed to this level today being categorised as having a pure tone and producing distinct clear notes, However, the developments towards the achievement of this purity of tone breed out the attributes of PVAs that are valuable in performance in the variable tone-colour mode. This group, while highly developed in performance is frequently simple in structure. The opposite is true of the PVAs that are considered acceptable today. Uncertainty of pitch of the higher formants of these instruments is bred out by control of tube morphology. Where a parallel tube is used this is attained by the provision of a flared bell and, on a conical instrument, by the development of uniform conicity, both these features pulling the formants into a harmonic relationship. The further refinement of a mouthpiece with a cup, throat and backbore increases the effective impedance of the tube, helping the player to excite the instrument's higher formants and to do this in a repeatable way. Instruments of this developed form were developed as early as the late bronze age in Scandinavia.

In its form of a voice modifier or megaphone, the PVA is most generally used for performance in the ritual. When used in this way it becomes effectively tied to its ritual

and its use outside this frequently forbidden. However, when the instrument breaks from this simplicity and becomes able to perform as a modern natural PVA, the resulting demystification - its appearance as an instrument with the voice of an instrument - frees it from the ritual restriction and it begins to fill a wide range of roles. However, even after millennia of use, instruments of all types still evoke particular responses in individuals. Their voices are still considered mysterious, martial, etc. and arouse generally similar reactions in all members of a particular society.

The Ancient Mediterranean World

The earliest datable records of PVAs are in the Middle East where naturally occurring materials such as animal horns and shells were used to form instruments. From about 2600BC, however, these naturally occurring types are joined in the instrumentarium by the tuba and this remains a common pattern of instrument usage right until the 6th century BC.

Of the animal horn instruments, the main source of knowledge, is based on the shofar and its highly elaborated and ritualistic usage. In spite of its range of two or, at most, three notes, an enormous variety of calls were built up using pitch, duration, volume and tone quality, to perform in both peace and war - in both uses, being seen as a religious observance. In the Scroll of the War.. .... (Yadin, 1962) quoted in Chapter 2 , an idea of the range of performance is given along with a picture of the great detail to which this performance had been ritualised.

The tuba emerges in two basic forms, the single cone variety which tapers smoothly from mouthpiece to bell and the two-cone type whose mouthpipe has one taper which leads into a rapidly opening-out bell. Their distributions remain essentially distinct, with the single cone to the northern part of the Middle East and the two-cone to the south for a considerable period. However, the conicity of the bell yard on the two cone type, eventually achieved a smoother, more "exponential" form which ran more smoothly into the tube yard. This development led to the convergence of the two types, obscuring their differences. The evidence suggests that the tuba was always made in sheet and never cast as were some of the northern instruments.

As early as the instruments of Tutankhamen (1350BC) the manufacture of the tuba had become a very elaborate technological procedure. The extant specimens from Tutankhamen's tomb demonstrate that these instruments were carefully made, presumably to the well-established accepted design of the period. In solving the major technical problem of manufacturing a tube, that of producing a strong air-tight seam, the craftsman had already developed a technique which is still in use today in instrument manufacture.

The Greeks adopted their own version of the two-cone tuba, the salpinx. Whether or not this was indigenous development or was a result of influence from North Africa/Egypt is hard to say. However, all depictions show salpinges with very narrow but clearly parallel tube yard and this contrasts with the conical tube of the two-cone tuba. What seems likely, therefore, is that the salpinx was developed on the northern side of the Mediterranean

either by the Greeks or, as the Greeks claim by the Etruscans, possibly as a result of a very low level of design diffusion.

At some time, the tuba acquired the mouthpiece that, combined with a suitable tube morphology gave the instrument a range of harmonically related formants. Several documentary references tell of the use of bone mouthpieces and the iconography shows large wedge-shaped features fitted onto the tips of instruments. Perhaps the Etruscans took this step along with the many others that seem to be attributable to them. Whether or not this was so, the Romans inherited the tuba from the Etruscans and utilised it in virtually all the roles that a modern PVA now fills.

Their main development was probably the refinement of its acoustic characteristics to bring its formants into harmonic relationships as it is seen in several scenes being played both with other PVAs and with the hydraulis. As well as this, the Romans developed forms with bell terminations reminiscent of the salpinx and utilised various cords both for carrying and for supporting the long instrument while being played. In use, both the tuba and cornu were frequently grouped in threes as opposed to the more common pairing of instruments in earlier times. Their technique for making the tube-yard seam remained similar to that used on the Tutankhamen instrument, it being soldered or brazed together.

The Etruscans and the inhabitants of the western seaboard of Italy were the first recorded peoples to use a wide range of PVAs. From about 500BC onwards, about ten different types of instrument were in use in this area. Several of these, such as the metal analogue of an animal horn, the lituus and the cornu appear for the first time in this area and of these, the latter two were adopted by the Romans and the cornu, along with the tuba, formed the staple assemblage of Roman PVAs. The lituus had survived for a time in its ritual role but then was supplanted by the easier-to-make tuba.

As used by the Etruscans, the lituus was a metal analogue of an animal horn extended by means of a long reed. Its early contemporary, the Cornu, however, while it had, no doubt, emerged from a natural form or its analogue, i.e. a highly curved animal-horn form, it had developed into a form which in no way resembled its pre-cursor, Thus, removed from the morphological restraints imposed by this earlier form, it was free to develop rapidly and to evolve forms that suited its use.

Roman Instrumental Usage

From its Etruscan form as a large diameter, very conical instrument, the Romans evolved a longer, smaller-bored tuba with a parallel tube over most of its length. At its bell end, these instruments sometimes terminated in a flat annular bell disc and sometimes in a cup-like feature similar to that seen on some salpinges. The curvature of the cornu evolved, by the turn of the millenium, from the oval form of the Etruscan instrument into a "G" shape. This tighter curvature of the mouthpipe brought the mouthpiece of the instrument comfortably to the lips of the player. As made by the Etruscans, the cornu had a cross-brace both to stiffen its form and to allow it to be supported on the shoulder of the player. The Romans extended this feature beyond the tube of the instrument itself, decorating its termination and, on occasion, using this as a supplementary standard in battle. On the three metre long instruments of the 1st century AD, this cross-brace had a

highly important role both in stiffening the instrument and in increasing its ease of handling.

Together, the tuba and cornu filled many roles in the day-to-day life in the Roman world, as in the military. They played in the circus, in the ceremonies of the state religion, the pomp of triumph and the ceremonial of the funeral. In the military, as the instruments of the infantry, they played to signal the watches of the day and to command and control in battle. Both the tuba and cornu, however, are long and large and, although their acoustic performance is enhanced by this, their portability is not. However, the Romans seem to have done nothing to overcome this, the only attempt to increase the portability being a local development in the Rhineland. Here the tuba was curved on itself twice to produce an instrument looking something like a modern trombone. These are identified, by their occurrence on the tombstones of cavalrymen, as instruments of the cavalry.

The Development of Instruments in Northern Europe

In Northern Europe two great schools of manufacture and performance existed during the late bronze-age (approximately 1600-500BC). Their conjunction in time, however, is occasioned in all probability by no more than the prevalent cults of the time being of a type which could incorporate ritual performance into their proceedings. In no other ways were the instruments or their usage similar. In Ireland, pairs of horns were used with one being end-blown and one side-blown, while in Scandinavia, the instrument pairs were of similar right and left-hand lurs. Being of large bore, with large mouthsupports or blowing apertures, the Irish instruments perform poorly as conventional PVAs. The lurs on the contrary had long tubes of very uniform conicity and well-developed mouthpieces. In the hands of only a moderately skilled performer, they produce a range of formants, very precisely related harmonically.

Being made in an area which used two-part moulds for casting, the Irish horns were made that way and the lurs too were made in the local fashion, i.e. by lost-wax casting. However, both extended the repertoire of the local founders considerably and very specific techniques of manufacture were used.

The Scandinavian Late Bronze Age

During the late bronze age in Scandinavia, the lurs evolved stage-by-stage from a simple short extended animal horn form with a mouthsupport, to a long, conical instrument with a mouthpiece of very modern appearance. The increasingly-close approximation of their form to an overall cone, along with the increasing roundness of their tubes has been charted in this study. Other features of the manufacturing technology such as methods of joining individual segments outline the progress of the manufacturer in refining and

improving his techniques. This technology, however, was for a purpose, the overall aim being to produce more functional musical instruments. The purpose was achieved by the casting of long tubes with thin walls and uniform morphology and then by assembling

these carefully to produce pairs which matched to a high degree. Decorative bell-discs adorned their bell ends and clear attention was paid to the aesthetic appeal of the instruments. Their tubes were carefully finished and, in one case, decorated by a carefully applied rifled pattern along its mouthpipe and tube yard.

Having been made in pairs, these instruments were most certainly played in pairs. They are accurately tuned one with another and in the case of a multiple find, two pairs are in tune, pair-for-pair. It seems unlikely that such well-made and functional instruments were played in unison as is commonly suggested. Their mellow tone combined with deep resonant bass notes provide the potential for performances of considerable complexity, both in terms of melody, rhythm and harmony.

The Irish Late Bronze Age

Ina similar way to the lurs, but utilising different manufacturing procedures, the Irish horns also evolved steadily throughout the late bronze age. From instruments utilising relatively simple three piece moulds, they were developed into large complex forms that used complex and novel moulding procedures. From integral construction their makers moved to prime manufacture, following which parts were added, initially by simple procedures but later by indigenously developed techniques akin to brazing. To achieve larger instrument sizes without consequential weight increases, thinner wall thicknesses were used which called for extremely careful core location and matching of core form to that of the mould. Chapletting systems were developed which allowed the core to be both located accurately and held securely in position while the mould was poured.

The sequences of manufacturing processes that can be isolated are intimately intermixed and show that many workshops were involved in the process of development and that contacts between these ensured that the developments of one area were shared with another.

The tradition of performance in this area is more difficult to recreate as the instruments themselves were used in pairs made up of one end and one side-blown instrument. The large size of the blowing apertures on these instruments indicate that they were used in the variable tone-colour mode and not in the same way as the lurs or modern instruments. This performance technique is unique both at this time and in this area, re-enforcing the view that these horns, as did the lurs, developed both manufacture and performance indigenously.

The Celtic World In a heterogeneous "nation" such as that of the Celts, in reality more a "nation of nations", the instrumental usage itself was very varied. The vast spread of the Celtic nations encompassed, at various times, most of Europe, bringing them into contact with both northern and southern traditions of musical instrument manufacture and usage

alike. In the past, however, in keeping with the diffusionist view of cultural spread, the southern connection has been emphasised and the credit for the Celtic instruments that have been recognised, attributed to diffusion from the south and east.

Next to the carnyx, the most clearly identifiable Celtic instrument is the Celtic curved horn. Of its origin in Ireland there is little doubt, the stages of its development and its relationship to the Irish bronze-age horns having been described in Chapter 6. The three examples of this form known from the Mediterranean attest to its use or knowledge of its use in that area, pointing to it having filled a role in more than one of the Celtic "Nations."

Similarly Northern in origin are the Celtic Litui. Their construction utilises the local manufacturing techniques and, in at least one area, that of Northern Germany, used a tradition of manufacture which is known to have existed during the Bronze-Age. Most impressive on these instruments, is their mouthpiece. These are well developed in form with a constricted throat and, in all, well designed to suit the instruments to which they were attached. Again this aspect of instrument manufacture, the design of mouthpieces, was known from the bronze age in Northern Germany/Scandinavia. The Celtic Lituus, however, was not always manufactured conservatively by the same techniques. In Scotland two-part moulds were used, in Europe, lost-wax, albeit with differences in the detailed manufacturing procedure. Thus, the design itself had been spread among the nations, each applying its own manufacturing expertise to their manufacture.

In Spain too, the Celts developed a functional mouthpiece. In that area it was made in clay, a material that facilitated detail changes in morphology to attain an organological aim.

The carnyx is, of course, the instrument, par excellence, of the Celts, and much has been said of its origins in this study. Unlike the other Celtic instruments, a southern origin does seem likely for this particular instrument. In particular, the experimentation with side-blown instruments in the area of Southern Italy from where both a side-blown lituus (Plate 7.1a, below) and a side-blown salpinx are known. In addition, the clear representation of a carnyx-like instrument in Maurya India points to its presence that far east in the 1st century AD.

Plate 7.1: An Etruscan Side-Blown Instrument and an Embouchure

It may be, of course, that the carnyx was the hybrid of northern and southern traditions. The Irish horns had been in use in Ireland for many years and some relict tradition may have survived to hybridise with instruments from the south. At least one coin shows a Celtic warrior carrying an instrument of hooked form like an Irish horn but carrying it

after the fashion of a carnyx. Whatever its source, the Celts made it their own, developing a form that is unmistakably Celtic.

A further way in which the Celts may have made a contribution to the contemporary instrumentarium is in the development of the double-curved instruments. These seem clearly to have developed in the Rhineland, most probably by Celtic craftsmen bringing to bear their experience in instrument manufacture.

Having a diverse assemblage of instruments, the Celts undoubtedly used these together as several documentary references report. In addition, the iconography shows two mixed assemblages of instruments, one of a carnyx and tuba and one of a Celtic curved horn, a tuba and a highly curved horn.

The Embouchure

Generally speaking, the accepted view of the development of embouchure mirrors that of music itself as emerging from the Dark Ages. Baines[235] says of embouchure that

> *"Up to, and partly including the 16th century, we find almost invariably an inflation of the cheeks, still in the manner of Roman trumpeters more than a thousand years before. Too constant a feature to be interpreted as caricature, it must perpetuate a primitive obedience to the animal instinct to feel at one's most formidable when making the loudest possible noise. With cheeks distended and lips under no further restraint than the pressure of the mouthpiece, a great blast produces a vibration of vast amplitude and the ear-splitting sound required of a military trumpeter by the ancient practices of warfare."*

Tarr[236] paints an equally uniform picture of embouchure practice with the present practice of playing without inflating the cheeks emerging in the late Middle Ages. Further to this he states[237] that no good professional player can play using the pressure method. ("Kein guter Berufsblaser konnte hingegen mit druckstarkem Ansatz blasen, ... ")_ Both these views of embouchure are clearly too clear cut and restrictive. In the case of the latter view, for instance, many jazz musicians play with what a more rigorously trained player would call a poor embouchure. However, they produce very credible performances and have extended the potentiality of PVAs more so than conventional players in recent years.

In the ancient world too, the picture is equally mixed, the assertion in Baines[238] that Roman trumpeters "almost invariably" inflate the cheeks being contradicted by the evidence. Tuba players sometimes blow this way but, more generally, hold the cheeks in while blowing; cornu players do generally puff out the cheeks. Salpinx players hold the

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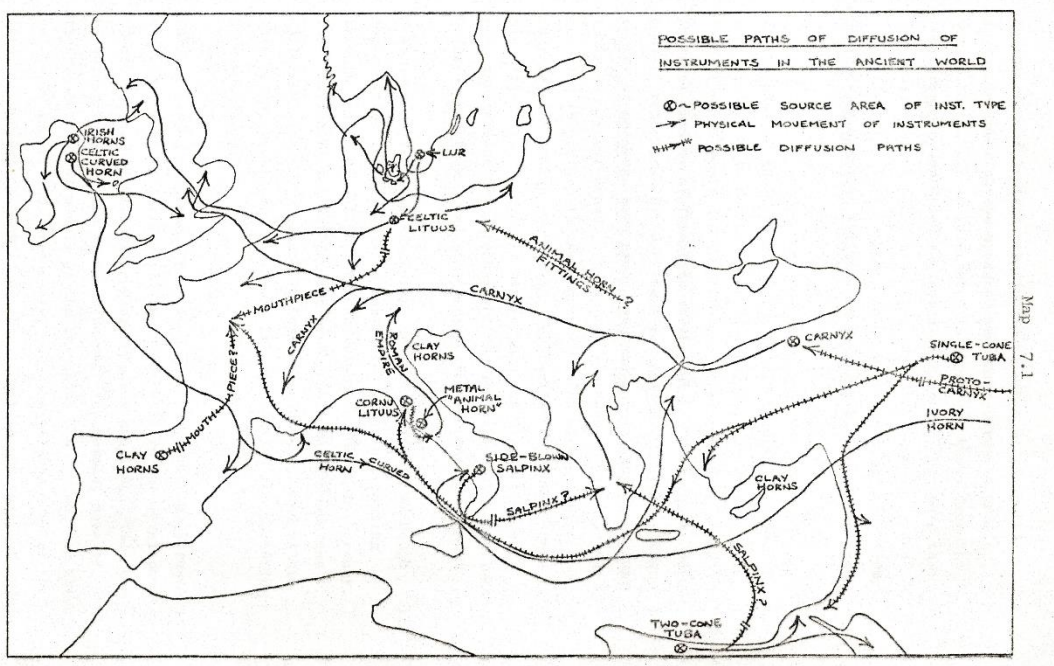
[235] Baines, 1976, 31.
[236] Tarr 1977, 60.
[237] Op cit, 60.
[238] Baines 1976, 31.

cheeks in while playing, often being helped by a phorbeia or strap around the cheeks. Several Egyptian and Etruscan representations show players quite clearly using a modern looking embouchure (Plate 7.1b, above).

Diffusion



Map 7.1: Trails of Instrument Influence

A somewhat cringeworthy representation which is left in because such views were still around in the 1970s

Map 7.1, above, provides a representation of the location and spread of instruments seen in this study. The production of such a map, however, is fraught with difficulties and is, at most, a rather simplistic representation of the facts. Most contentious of the simplifications required when producing such a representation lies in the drawing of lines from A to B and the defining of the meaning of these lines. This study has confirmed neither the present-day predisposition to see all processes of development as indigenous, nor the earlier fashion of their all having diffused from the Near East.

The term "diffusion" is itself too blunt an instrument to be of great use without conditioning prefixes. It must be controlled and directed to tell much more about the nature of diffusion that took place. In the case of both northern instrument types studied, developmental sequences are apparent from very primitive forms to the later complex and elaborate instruments. To this extent, both these schools of manufacture and performance are clearly indigenous and encompass a complex of inter-relating attributes that are unique to the area in question. However, within that area, likely sources of the instruments themselves can be outlined; Scania in the case of the lurs and north·eastern Ireland in the case of the Irish horns. Of the very early stages of these instruments, no firm conclusion can be drawn. Perhaps the peoples who settled the areas when they were originally colonised or a subsequent wave of immigrants brought with them the idea of simple blowing horns, a very low level of user diffusion.

In the case of Ireland, continuity of usage of their PVA form into the iron age produced the large riveted Celtic Curved Horns. Three references to these are known from the Mediterranean world and the solid line connecting these to the Mediterranean area on Map 7.1 represents transport and not diffusion. There appears to be no evidence for the form having diffused from Ireland, to be manufactured and adopted to suit another society.

In the case of the carnyx and the Celtic lituus, however, the contrary seems to be the case. The carnyx, for instance, is found from Maurya India to iron-age Lincoln, appears in an enormous variety of forms and is the subject of frequent documentary references by the Greeks and Romans. In the Celtic family of nations, each group used the carnyx adapted to suit their own requirements. The animal-headed termination was modified to perform the secondary function of a standard and featured the design current in that particular group. More significantly, the mode of manufacture was also varied to suit the manufacturing technology available locally, sometimes using a brazed seam and sometimes a riveted one.

A similar pattern was seen with the Celtic lituus, although the distribution of these is restricted to an arc passing through Scotland, Holland, the Rhineland and Northern Germany. The Scottish instrument is made by two-part mould technique while the others are generally lost-wax cast and, even within this group, great variety exists in the detailed manufacturing procedure adopted.

Further strong evidence for diffusion exists, with the Etruscans and other western Italics playing a key role in the development of new forms. Of diffusion prior to these peoples, little can be said because of the scant evidence. The Romans, however, took the two basic instruments of the Etruscans and spread them throughout their Empire and, presumably, made these locally where the local technology existed to do this. Only in one case did local adaption occur, in the Rhineland. Here the Roman tuba was curved back on itself twice to produce a shorter form presumably more convenient for the cavalry to handle.

If the evolutionary process, in which the PVA proper developed from the megaphone, really did take place then the argument for polygenesis is strong. Language is a universal phenomenon and the use of external voice modifiers are likely to be almost as widely distributed. Thus, the path from sound induced by vocal apparatus to that induced from the lips alone, perhaps having passed through a variable tone-colour stage, could have occurred at many points.

Two areas seem to provide links between the megaphone and PVAs proper. In Egypt where, during the 4th Dynasty (2723-2565 BC) a megaphone was used to summon troops, this paralleled very closely the use of the trumpet in this area sometime later. In Ireland, the side-blow horns with their large blowing apertures are capable of use both as megaphones and variable tone-colour instruments.

Clearly, the most difficult part of a PVA to fashion is the mouthpiece, although some manufacturing processes allow its manufacture more readily than others. It is reasonable, therefore, that those areas with the most appropriate technology produced the first mouthpieces. Scandinavian manufacturers for instance built up their expendable wax pattern from pieces of sheet. This is clearly visible on several instruments where the shape of the individual sheets can be made out. The flexibility of the wax medium allowed the maker full freedom to form the space between the throat and the mouthpiece rim to suit himself thus leading to the very sophisticated mouthpieces seen on the lurs. In the case of the other, possibly very early, mouthpieces, those from Numancia, these too are produced in a medium that allows simple generation of the form, i.e. clay.

With instruments made of sheet—metal, the generally adopted technique in ancient times was to cast mouthpieces. However, even this involved the complex job of producing the

mouthpiece throat accurately. Thus, these cast mouthpieces were preceded by bone ones in which their internal form could be carved more readily. Documentary references tell of the practice and several iconographic sources depict mouthpieces of large external dimensions pushed onto the tip end of instruments. This practice may well have developed as a result of the manufacture of instruments from animal horn, where the solid tip would allow a mouthpiece of some form to be carved out. In addition a passageway would need to be drilled through into the horn cavity, automatically creating a constricted throat.

If diffusion of ideas did take place in the ancient world of PVAs, then it is the mouthpiece that was most likely to have featured strongly in such an exchange of ideas. Map 7.1 shows possible paths (crossed lines) of diffusion, where it could have spread from either Scandinavia or Spain.

Thus, the evidence of PVAs shows a mixture of types, some have been transported from one culture to another and elaborated by the receptor society, others having originated and developed in single societies. Of the very early days of PVAs, when made entirely of natural materials in the pre-metal ages, nothing is known. It would seem reasonable to suppose that their use was widespread, although nothing stronger than supposition can be justified.

The Organological Specificity of Technology

All instruments which evolve, go through the process in which existing dimensions are matched either visually or otherwise and the resulting dimensional drift leads to a gradual change in morphology. When such instruments are manufactured using the general technology of the day, they appear to evolve principally in aesthetic and organological ways. Thus, when similar instruments are manufactured in different regions whose manufacturing technology sub-divides into various different industrial groups, different processes are used to make what is essentially the same instrument in different areas. This is seen, for instance, in the case of the Celtic litui where instruments with very similar

morphology were made using two-part moulds, and lost-wax techniques, some of which involved final assembly using a "solder." In this situation no manufacturing technique became very specific to musical instruments, presumably because the local technology was sufficient to produce instruments to an acceptable standard. Because of this manufacture as a general process, probably along with other items which required a similar manufacturing technology, it is possible that the instruments themselves were perceived as general items made to be used in a general way. If this were so, then the instrument would most likely be free to be used in all the ways open to PVAs including the "musical."

In the Mediterranean world, the majority of instruments were made from sheet and thus, the major technical problem associated with manufacture was that of making a seam. As early as the time of Tutankhamen the technique of interleaving the two edges of a seam was developed in order to hold these together while brazing the seam. In the case of the Tutankhamen instruments, one edge of the seam had a series of slots along its length which were bent alternately up and down and the other edge folded over and fed in between these tabs. The whole seam was then brazed and swaged over to smooth in the tabs, although not necessarily in that order. See image above (Plate 7.2)

A later instrument has a similarly made seam although the seam overlap is attained using wedge-shaped teeth cut into one side of this. Modern instrument bells are invariably made of sheet in this way, although the tube or bell may be subjected to working after the seam has been brazed, thus resulting in a uniform thickness of metal over the seam.

Other parts of instruments such as mouthpieces and bosses were cast using even older metalworking techniques that allowed the complex form of these to be produced. The morphological flexibility offered by casting was utilised to enrich instruments with elaborate decoration such as is seen on the Celtic tubae.

In clear contrast to those areas where "off-the-shelf" technology was used to manufacture instruments are the areas where a very specific manufacturing technology emerged that

was devoted almost exclusively to the manufacture of instruments. Significantly in both areas where this was so, Ireland and Scandinavia, the manufacture involved casting; the more ancient, and spectacular, form of metal-working. In societies such as these, all facets of life would be closely integrated as would all the facets of life of the artefacts that it produced. Thus, for a lur or an Irish horn, the creation of the original form must have been a significant event. The technique used, casting, justifies the term "creation" entirely. A founder takes a jumble of scrap or ingots and creates from it an artefact that appears as the mould is broken open. Failures of the process add immeasurably to the mystery that surrounds it. Explanations for success or failure would have invoked the supernatural as they still do today.

In contrast to the creation by casting, the sheet-metal worker forms an item from sheet and this emerges as he works, guides and coaxes the metal to the form he wants. That is not to deny the use of ritual in the manufacture of fabricated items, nor the use of fabricated items in ritual. The Celtic curved horns and the horned helmets clearly employ similar manufacturing technology and were, presumably, similarly associated in their ritual use. Even today, ritual words are extensively employed in sheet-metal working, particularly when recalcitrant metal flows "the other way!"

Many examples of ritual in manufacture are reported and these seem to perform two particular functions in that they provide an organised basis for the recording, storage and retrieval of precise information and that they invest the artefact its maker and its user with special powers. Such a ritual practice concentrates the efforts of the manufacturer onto a narrower range of products and techniques and it is this specialisation that leads to rapid development.

In the case of the Irish horns, these are all made by the same basic process, in spite of regional variations in design and detailed manufacturing procedures. However, this manufacturing technology itself shows continuous experimentation, development and improvement. Indeed, in this area, development of the complete technique of chapletting to produce tubes with uniform wall thicknesses can be followed stage by stage. Such development is contingent on the deep understanding of the basic properties of the materials used, i.e. both the metal, bronze, and the mould material,·clay.

In spite of the different manufacturing technique used with the Scandinavian instruments, much of what has been said of the manufacturing of the Irish horns applies equally well to them. Their makers used a technology very specific to the lurs, in fact, of little use in manufacture other than for long tubular instruments. This concentration similarly led to experimentation and, eventually, to the development of the manufacturing process to a very high degree of sophistication. As with the Irish technology its high degree of specialisation was to prove fatal as, when elements of the tightly interconnected ritual

changed, the whole structure collapsed. Thus, the processes that had been developed for such a specific aim collapsed with the ritual.

The Use of Standard Measures in the Design of Instruments

The advantage of the abstraction of dimensional data is that, along with the abstraction of writing, i.e. the storage of words and numbers in graphic form, it allows data to be stored. However, such an abstraction seems to offer little advantage to a pre-literate society where one would expect greater use to be made of concrete forms of storage of dimensional data, i.e. models. In expressing the dimensions in terms of the best-fit regression lines ($y = mx + c$), a mathematical technique is being used which is based on the use of an algebraic expression of geometrical features which developed during the 17th century. While it is a useful descriptive tool for comparing, contrasting and otherwise analysing geometrical shapes it must be used with circumspection. However, there is little doubt that the concept of slope was understood and that, in the case of several instruments, the maker was aiming for an overall uniform slope throughout the whole instrument's length.

The need to create a tube of uniformly increasing diameter calls for the ability to produce regular increments in diameter along its length. Hence, the requirement for a standard unit by which the tube's diameter can be regularly increased. This alone seems sufficient to account for the use of a unit like the brin and its use for both length and diameter suggest that the idea of unit increase in diameter per unit (or multiple units) of length was well understood.

While the lurs are of a form that is complex and not easy to analyse mathematically, their sub-division into segments does provide some basis for analysis. Thus, on these instruments the lengths of individual segments can be measured, along with their end diameters, giving some degree of sub-division of the tube. However, the Irish horns are not sub-divided in this way and their conicity and high degree of curvature makes them difficult to analyse mathematically. Where measurements could be taken, these have shown a considerable degree of consistency both in wall thickness and tube diameter and suggest that further detailed metrological analysis of these might well prove fruitful.

The Interpretation of Mathematical Data

Much emphasis has been placed on the relevance of the mathematical data as a tool for reconstructing manufacturing techniques. In particular, roundness and diameter are parameters of considerable·interest. This study appears to be novel in proposing that the difference between technical processes, generating inherently round forms, and human perception could possibly be quantified as the result of experimentation. It may be, therefore, that the proposition itself is false. Unfortunately the parameters of roundness and diameter are not of great interest to the perceptual psychologist as both these concepts are rather technical and he is more concerned with "size" and "shape" in a much more

general way. In addition, tests allowing multiple modalities are considered to be poor experimentally and all but one modality are generally designed out of the experiment. However, in drawing our conclusions as to the ability to perceive small increments we are

particularly interested in the ability of subjects when they have available the full range of visual and tactile processes to enable one to make judgements.

Experiments to test for these abilities are outlined in Appendix III. However, being somewhat novel and requiring a great deal of preparation of both specimens and experimental procedure, no attempt was made to carry these out during this study. One of the prime considerations when making this decision was the realisation that a whole series of preliminary tests would need to be carried out before the tests proper could commence. No data at all is available on the level, say, of roundness at which to attempt discrimination, let alone the effect of the number of faces on the polygon or the radius between these. It is hoped, therefore, that this work can be carried out in the near future.

An Overall Appraisal of this Study

When beginning this study, one of the main aims was to investigate the interrelationship between the various instrument groups which existed prior to 500AD. To this end, the major two groups studied have been shown to be quite independent both of each other and of other groups of instruments of the time. In the case of the southern instruments, interrelationships have been demonstrated that tell of the inter-mixing of ideas and cross-fertilisation between the various cultures.

The sequence of developments in the manufacturing of the Irish horns have been investigated and described in detail for the first time. This has demonstrated the presence in Ireland during the late bronze-age of an active, progressive and successful school of manufacturing not previously recognised. Their products show the use of increasingly-complex technology which is here demonstrated to be indigenous to that area. In addition, the organological features of these instruments have been studied and a mode of usage proposed that had not previously been considered.

A considerable amount of precise metrological work was carried out on the lurs during this study, often under very difficult conditions. The analysis of this data has led to novel conclusions about the principles underlying their design. This interpretation of dimensions on artefacts from as early as the bronze age opens up the whole area of the analysis of the design of early objects and the understanding of the concepts of measurement and of length, diameter etc. by early manufacturers. In addition to this, the use of figures for the roundness of objects along with those obtained for perceptual experimentation as a means of determining manufacturing techniques is proposed in this study for the first time.

In the study of the tuba and the Etruscan and Roman iconography use was made of the work of acoustic theory to trace the patterns of developments seen. This, combined with the large corpus of iconographic material collected during the study has established dates for the changes in instrument morphology, particularly during Roman times.

The corpus of extant and iconographic material has also enabled the place of the Etruscans, in the history of PVAs, to be stated clearly for the first time.

Celtic instruments have never previously been considered in entirety in one study. In this work, their range, their similarities and differences have been studied. An overall picture of the active musical life of this "nation of nations" has emerged and their wide diversity of instruments forms and their sources outlined.

A comprehensive catalogue of contemporary references to PVAs of the period has been produced. This corpus of some 650 entries forms the basis upon which this study is written and remains to be modified, updated and, where necessary, corrected by future scholars. Thus, this increasingly comprehensive document should provide a firm basis for future study.

In a subject so vast as that of the PVAs in antiquity, no single study can cover the whole field either in breadth or depth. However, this study has examined the large range of instrument types and put them into an overall context. In addition it has highlighted particular areas where more detailed analysis is required and produced a catalogue which, it is hoped will enable future scholars to begin their study of these instruments with ready access to at least a good proportion of the available material to hand.

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