CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.1. Introduction

Stumpf was the first psychologist who discussed the AP of Wolfgang Amadeus Mozart (1756-1791) theoretically in 1883 and marked the beginning of the scientific examination of AP (Wedell, 1934). Since Stumpf, studies, though giving rise to many controversies, have covered most areas of AP. Efforts were mainly put into the understanding about its nature, processing, training methods, assessment, influencing factors, characteristics and value.

2.2. Pitch and Musical Pitch

Pitch has its physical property. This is primarily the “frequency” (Olson, 1967, p.25), the “repetition rate of the waveform” (Moore, 1997, p.177) or the “vibration” (Gregersen, 1998, p.221) of sound. Rasch and Plomp (1999) considered pitch as “the frequency of a simple tone” and “the fundamental frequency of a complex tone” (p.94).

Tones are measured in Hertz (Hz), i.e. cycles per second. They vary from highness along the continuous dimension of frequencies. Pitch is the perceptual attribute of tone. It is the logarithmic function of each tone based on the distance of a logarithmic scale. In traditional western music, there are 12 semitones of equal distance per octave in the log frequency. This pattern appears in every octave. These 12 tones in every octave are assigned the same letter names (Krumhansl, 1991). The seven white keys are named A, B, C, D, E, F or G. There are five black keys between A and B, C and D, D and E, F and G, and G and A. If they are sharp, i.e. a semitone higher than the white keys to their left, they are called A-Sharp (#), C#, D#, F# and G#. If they are flat, i.e. a semitone lower than the white keys to their left, they are called B-Flat (b), Db, Eb, Gb and Ab. Each black key has two different names, depending on its sharp or flat nature. They have another psychological name, the pitch class or tone chroma. Each note bears a different pitch height. Therefore, a note of different octaves possesses the same pitch class with different pitch heights.
Pierce (1999) related pitch to a sense of hearing. If it is two to four cycles long, it is only a click. Below 1000Hz, a sound should be at least 16 cycles long to be a pitch. If above 1000 Hz, it should be at least 32 cycles per second. It takes time for a human auditory system to form a sense of pitch in sound. The number of cycles in sound necessary to produce a sense of pitch depends on the number of cycles needed to form the vibration along the basilar membrane in human ears. Every musical tone has overtones of its own. Its pitch is characterized by its first six overtones.

Pitch is not limited to its physical property. It is an auditory ‘experience’ (Lewis, 1937, p.121) or ‘sensation’ (Helmholtz, 1954, p.22; Seashore, 1938, 1967, p.53) from the highness in the music scale or from the frequency of sound. According to Levitin (1994), pitch is not a single frequency, but a range of frequencies. Some people may have a wide range, but some may have a narrow one. They judge tones with the midpoint of the category, called the ‘focal tone’. Levitin (1994) asked AP subjects to decide tones in 20-cent increments whether they were in the scale or not. As a result, subjects rated focal tones as the judgment of the category. And AP has a ‘narrow anchor’.

2.3. Relative Pitch (RP)

One skill in identifying tones is RP. It is an ability to identify tones with referential tones (Lundin, 1967; Campbell & Greated, 1987; Benguerel & Westdal, 1991; Butler, 1992; Barnea et al, 1994; Krieger, 1997; Burns, 1999). It is a skill of telling pitch differences (Seashore, 1938, 1967), intervals (Révész, 1953; Siegel & Siegel, 1977; Benguerel & Westdal, 1991; Sundberg, 1991; Levitin, 1998; Burns, 1999), tonal relationships (Miyazaki, 1992; Brown, 1999) and melodies (Miyazaki, 1992; Burns, 1999) with references. RP possessors may develop an internal scale (Ward, 1999) or references (Campbell & Greated, 1987) for comparisons. They must rehearse the references frequently and keep them in their working memory in order to compare tones (Crummer et al, 1994). In RP judgments, a musician, given a referential tone, can discriminate a stimulus tone as identical, lower or higher. An unmusical person may only know the second tone as being different only
RP is rare in the general population (Burns & Campbell, 1994), but it is common in musicians (Campbell & Greated, 1987; Benguerel & Westdal, 1991; Zatorre et al., 1998; Burns, 1999) and music listeners (Butler, 1992). It can be learnt easily (Burns, 1999).

2.4. Definition of AP

To give AP a precise definition is difficult since different investigators demand different levels of accuracy (Brady, 1970) or employ different techniques in testing (Vernon, 1977). Nevertheless, many researchers have tried to define AP to its fullest extent.

The first comprehensive definition of AP was given by Petran (1932). He described AP as an ability “to give quickly and correctly, without reference to any standard tone, the names of tones that they hear, and also the ability…… to sing or whistle any tone which may be called for by name” (p.1). The ability includes naming and singing tones. The judgment should be quick and correct. Based on Petran’s definition, Bachem (1955) defined it to a fuller extent. He referred AP to ‘the faculty of recognizing and defining (e.g. by naming or by singing) the pitch of a tone without use of a reference tone. This recognition or reproduction of a tone may be as spontaneous, immediate and certain as the identification of a colour (e.g. green, without any comparison with a standard spectrum)” (p.1180). He emphasized that the judgment should be spontaneous, immediate and certain. Profita and Bidder (1988) amended that the judgment should be effortless.

Investigators, from Boggs (1907), Révész (1953), Bachem (1955), Brady (1970), Miyazaki (1988), Takeuchi and Hulse (1993), Moore (1997), Zatorre et al (1998), Ward (1999) to Stary (2002), referred to AP as an ability to identify as well as to produce musical tones. In the identification, the possessor can name or point out testing tones. In production, one can sing, whistle, hum (Petran, 1932; Révész, 1953; Brady, 1970; Lockhead & Byrd, 1981; Butler, 1992; Travis, 1996; Howe et al, 1998; Stary 2002) or adjust the frequency of a tone generator (Parncutt and Levitin, 1999).

Some investigators related AP to brain functions in the long-term memory. Crummer et al
(1994) referred AP as an ability ‘to identify a pitch without previous cuing, by relating the presented pitch to a long-term memory template or array and conversely (to be) able to correctly produce a pitch on request” (p.2721). Levitin (1998) associated AP to a cognitive ability ‘to produce or identify tones without reference to an external standard, presumably through reliance on a highly developed internal template or self-referencing mechanism’ (p.2 of 14).

Summing up the above definitions, AP is a spontaneous, immediate, effortless, certain and accurate tonal judgment without referential tones. These criteria match with the “Absolute Judgment Theory” (Wever & Zener, 1928; Garner & Harald, 1951). The possessor can use recognition (naming or playing test tones in another instrument) or production (singing, whistling, humming, or regulating tones in the tone variator) to show the trait.

2.5. Terminology

Petran (1932) was the first psychologist to clarify the terminology of AP. He mentioned Abraham (1901) found ‘memory for AP’ most suitable, Meyer (1911) used ‘absolute determination of pitch’; Ladd and Woodworth (1911) used ‘judgments of absolute tone’, Copp (1916) used ‘positive pitch” and Watt (1917) used ‘absolute ear’. ‘Perfect pitch’ was used at his time too. Most English researchers and physicists used “AP”. He considered “AP” the most appropriate.

2.6. Occurrence of AP


AP occurs more in musicians than in the general population (Sacks, 1995; Travis, 1996). Harris (1926, cited in Petran, 1932) found out that one out of seven (14.3%) students at the Royal Academy of Music could name and sing tones accurately. Révész (1913, cited in Miyazaki, 1988) estimated 3.4% among musicians, and he (1953) quoted that 5% of music students, orchestra-players and piano-tuners in Chicago had AP. Welleck (1963, cited in Miyazaki, 1988) noted 8.8% among musicians. Vernon (1977) reported less than 5%. Spender (1980) indicated that 87% of specially gifted concert performers had AP. Miyazaki (1988) approximated that no less than half of the music university students in Japan possess AP. Burns & Campbell (1994) reported that only a few percent of western musicians possess AP. Baharloo et al (1998) suggested that 15% of musicians and music students in music conservatories have AP. Dowling (1999) speculated that 4% to 8% of musicians in western countries and 50% in Japan have AP. Gregersen et al (1999) found that 24.6% of music students in conservatories, 7.3% in music colleges and 4.7% in university music programmes had AP. AP is more prevalent in Asian (32.1%) than non-Asian (7%) students. The AP prevalence is higher in students at music conservatories than at other music institutions. Terhardt suggested 8% of students at music conservatories of Europe and the United States being AP possessors. Bachem (1940) and Richard (1942)
pointed out that many great musicians have no AP indeed. In summary, the estimation of AP in musicians is around 5% to 25% in western countries and 50% in Japan where early music training is prevalent.

AP is more commonly found in musical savants (Rimland & Fein, 1988; Miller, 1989; Heaton et al, 1998), autistic (Young & Nettbeleck, 1995; Heaton et al, 1998), blind (Bachem, 1940; Neal, 1983; Welch, 1988; J.T., 2000) and Williams syndrome persons (Lenhoff et al, 2001) than in the general population. Concerning those with the severe learning difficulty, Hill (1977) estimated a 0.06% occurrence of the musical savant. Rimland (1978) approximated 10% of the musical savant in autistic children. Rimland and Fein (1988) approximated the prevalence of AP in autistic persons is higher than that in the general population, around 5%. From blind samples, Révész (1953) quoted that 14% had AP, while only 5% of seeing persons had. Neal (1983) found 40% to 60%, Welch (1988) found 76% boys and 46.2% girls, and J.T. (2000) found 58% had AP.

2.7. Different Types of AP


2.7.1. Pseudo-AP

The term ‘Pseudo-AP’ was suggested by Bachem (1937, 1955) to describe those who claim themselves AP and if fact identify notes through guessing. They identify tones with an average error of five to nine semitones. The error can be narrowed by training. The judgement is slow, undecided, uncertain, guessing and is based on the tone height not the tone chroma. The accuracy is especially low for chords, keys, octaves, unfamiliar timbres and away from the middle registers. It cannot be recognized as AP.

2.7.2. Quasi-AP

‘Quasi-AP’ was another term suggested by Bachem (1937, 1955) to describe the
judgement based on the comparison of tones with internal standards. Singers may memorize the lowest singing tone, from which other tones are estimated. The standard may shift a semi-tone up or down. The interval sense may be inaccurate. The judgment may be one to two semitones deviated. The time used for comparisons is long. If the response is immediate without after-humming, the judgment would be very wrong. Piano players may memorize the middle C as it is the first note to start with in learning (Bachem, 1937, 1955; Révész, 1953). String, woodwind and brass players may memorize A (Bachem, 1937, 1955; Révész, 1953; Costall, 1985) as the concert A is the standard tone for the orchestral tuning. They then play the rest of the music by RP. These persons cannot be viewed as AP possessors. As a matter of fact, many musicians who claim to possess AP have only the RP. The judgment is based on the interval sense from the standard. The tonal judgment within three octaves above the standard may still be fast and certain. Outside this range it is slow and inaccurate. It is hard to differentiate a quasi-AP from a true AP possessor in terms of judgments. However, quasi-AP persons require more time to judge tones, especially if the tones are away from their internal references (Ward, 1999).

2.7.3. Genuine-AP

‘Genuine-AP”, still another term by Bachem (1937, 1955), refers to those who identify tones without references. It is classified into three sub-categories, i.e. “Universal”, “Limited” and “Borderline”. In order to determine whether there is genuine AP or just quasi-AP, Stanaway (1970) examined an AP student suffering from tinnitus to see whether his AP judgment fluctuated with the pitches of his tinnitus. The quasi-AP is based on an internal reference tone created by tinnitus. Results showed that tinnitus is unlikely to be the reference. It supported Bachem’s viewpoint that genuine AP does exist.

2.7.3.1. Universal Genuine-AP

The tonal judgement of the “Universal Genuine-AP” over the entire piano scale and for all musical and non-musical instruments is correct, immediate and certain. No semitone or octave errors are made. Their AP judgments for singing, humming, whistling, bells, glasses,
spoons and automobile horns are accurate too. The judgment is based on the immediate recognition of the tone chroma. The tone height is only used for determining octaves. This type is called ‘Infallible and Universal Genuine-AP’.

AP possessors may make octave errors, half-tone errors in one direction if instruments are not tuned to A440, half-tone errors lower in the highest region and higher in the lowest part, and errors from tones of non-musical instruments. These errors are so common that they are widely accepted. This group occupies the largest percentage of AP possessors. They are called ‘Fallible and Universal Genuine-AP’.

2.7.3.2. Limited Genuine-AP

Some AP possessors have AP over a limited range in the piano and other musical instruments, mostly three to four octaves. They are called ‘Genuine-AP of Limited Region’. Some AP possessors identify tones of one to several musical instruments. This kind is limited to timbre. These possessors are called ‘Genuine-AP of Limited Timbre’.

Some have AP limited to one or two familiar instruments and to the middle or the most familiar range. They are called ‘Genuine-AP of Limited Region and Timbre’.

2.7.3.3. Borderline Genuine-AP

Some AP possessors have many fifth, fourth and third errors in addition to semitone and octave errors. These errors occur even in the middle range of the piano and tuning forks. Their tonal judgment is slow and uncertain. They are called ‘Inaccurate Genuine-AP’ possessors. Some possessors even exhibit varied AP accuracy with musical instruments. These possessors are called ‘Inaccurate and Variable Genuine-AP’.

2.7.4. Partial-AP

‘Partial-AP’ was a term used by Takeuchi and Hulse (1991) to describe AP persons who develop AP only for white key tones. They judge black key tones relatively to their neighbouring white key tones. Errors are mainly on semitones and black key tones. They mistake black key tones for the neighbouring white key tones. There are two reasons. First, students start with white key notes which form the C major scale. Second, black key notes
are named in terms of their neighbouring white key notes with sharps or flats. Children must learn white key notes before they learn black key tones. They develop AP for white key tones before black key tones. There is a critical period in early childhood to develop AP. After this critical period, it is difficult (Copp, 1916; Jeffress, 1962; Ward, 1963; Sergeant & Roche, 1973; Miyazaki, 1988, 1989, 1990; Takeuchi & Hulse, 1991). When children start to acquire AP for black key tones, the critical period is over or the ability in AP is declining. As a result, they can only develop AP for white key tones. They compare black key tones with the neighbouring white key tones.

2.7.5. Residual-AP

Halpern (1989) found that non-AP adults can approximate tones of familiar melodies near to the designed tones. They still keep some AP even though long after the critical age. His finding gave a background to the ‘Residual-AP’. Takeuchi and Hulse (1993) employed this term first. They postulated that everyone initially can acquire AP. As children grow older without much music training or with the training in RP, their AP declines. When they become adults, few may still keep some AP. This is the ‘Residual-AP’. Adults with residual-AP can identify some tones, approximate pitches of familiar songs and judge keys. Saffran and Griepentrog (2001) guided 8-month-old infants to track AP patterns in tonal sequences in which adults use primarily RP. They gave the same test to Mandarin speakers who could do no better than guessing whereas the infants showed AP. They proposed that people may be born with AP. It diminishes after language or RP is developed. The infants’ pitch memory may be different from the AP in musicians. It may be related more to ‘Residual-AP’. Ordinary people do not need this refined sense except musicians. Once language is learnt, AP is not useful anymore. RP is more useful and becomes dominant over AP. Bergeson and Trehub (2002) examined the stability of pitch in maternal singing to infants. The mothers showed great consistency in pitching. People can recall familiar songs in nearly the same pitch. The finding supports the idea that adults have residual-AP.
2.7.6. Latent-AP

Levitin (1994) proposed that everybody has AP to some extent. Non-AP subjects were asked to sing familiar songs. In total 12% to 40% of the subjects sang the first three notes correctly in one or two trials and 44% made errors within two semitones. There may be some degree of absolute memory for pitch found in the general population, which is called the ‘Latent-AP’. They possess pitch memory but do not learn to label pitches due to the lack of music training.

The term ‘Latent-AP’ was also used by Ward (1999) to describe people who judge tones without knowing how to name notes. Deutsch (1999) recruited seven Vietnamese speakers and 15 Mandarin speakers to read out 10 Vietnamese and 12 Mandarin words respectively at different times. The tonal production of these words was found consistent. The Vietnamese speakers demonstrated a mean pitch difference of less than 1.1 semitone and the Mandarin speakers of less than 0.5 semitone. It was postulated that they make use of their AP templates in speech. People may have ‘latent-AP’, like those who can sing back tunes in similar pitches (Levitin, 1994). Everyone has some form of AP even though one cannot put labels to notes (Abrams, 2001). So far, no person with ‘latent-AP’ has been reported in the literature.

2.7.7. AP 1-4

Baharloo et al (1998) developed a test for AP. Forty pure sine wave tones and real piano tones are used as test stimuli respectively. AP persons are classified into four groups according to their achievement, i.e. AP-1 to AP-4. AP-1 possessors can identify piano and pure tones with high accuracy. AP-2 and AP-3 can identify both tones with less accuracy. AP-4 can identify piano tones accurately, but judge pure tones poorly. Concerning their processes in pitch perception, AP1 to AP3 can identify tones with their fundamental frequencies. AP4 are a distinctive type of persons who have an inborn ability to make use of timbre and tone harmonics to identify tones.
2.7.8. Codetta

Of the six types of AP, only the genuine-AP, partial-AP and AP1-4 can be called AP possessors. These possessors can identify or produce tones absolutely, certainly and immediately even though the accuracy varies.

2.8. Theories of AP

AP can be theorized with two trends, i.e. the heredity and the innate approach. In the heredity approach, AP is limited to very few people. In the innate approach, AP is a potential to everyone. Both approaches emphasize that music training is inevitable to reveal the trait, no matter whether there is a critical period for training or not.

2.8.1. Heredity Theory

The first theory explaining the aetiology of AP is based on heredity. It was first postulated by Stumpf (1883, cited in Neu, 1947 and Crozier, 1997) and followed by von Kries (1892, cited in Petran, 1932), Whipple (1903), Wundt (1911, cited in Petran, 1932), Révész (1913, cited in Petran, 1932 and in Neu, 1947) and Petran (1932).

It was not until Bachem (1940) who examined the genetic factor in a large scale study and formulated the heredity theory. Bachem (1940) reported that one-third of his 103 AP subjects claimed their AP was inherited. One blind person without musical training could recognize tones immediately after he knew how they were labelled. Five prodigies who started music training between two to five years old had AP within two weeks to half a year after training. Three of them had relatives with AP. One subject had AP at one year old. Forty-one subjects had relatives with AP. Bachem (1955) studied two identical twins who separated early in age. They possessed the same type and degree of AP. To Bachem (1940, 1955), AP occurs more in musicians than in the general public, especially those with early musical training. Attention to tones in the early childhood is important. However, musical experience is important only in improving the acuity of AP. The lack of music experience makes AP decline. Among his cases, two musicians found their AP declining with increasing deafness. A greater acuity of AP was found in violinists than in pianists.
because violinists paid more attention to tuning. Despite the music training, AP is rare among the general public and musicians. For Bachem, heredity plays a prime role in the development of AP. And some people are genetically apt to inherent AP.

Profita and Bidder (1988) found that there is familial segregation in AP. Out of 19 subjects, 16 had first degree AP relatives. AP is recognized at an early age. Parent-to-child inheritance is predominant. Children must be exposed to instrumental playing at their early age in order for the trait to develop. Prominent musicians, such as Arthur Fiedler, Egon Petri and Vladimir Horowitz had no AP even though they started their music training in their early age. This gives support to the idea that AP is innate.

In the survey by Gregersen and Kuman (1996), from 101 AP subjects, 37% of the probands reported first or second degree relatives with AP and 21% of these cases included one or more siblings. The percentage of siblings of probands having AP was 26% and that of parents of probands was 5.5%. The data showed strong familial aggregation and early music training was reported.

Travis (1996) quoted two surveys to support his genetic viewpoint. The first one was run by P. K. Gregersen and M. de Andrade. From 126 AP subjects, 5.5% reported that their parents had AP and 26% had siblings with AP. Only 1.1% of non-AP musicians reported having parents with AP and only 1.3% of this group reported siblings as having AP. The second study was carried out by S. Baharloo et al. From 600 musicians, 40% of the AP musicians reported having relatives with AP while only 12% of the non-AP musicians had AP relatives. Both studies reported the early music training in AP, but only genes enable one to possess the trait.

In a survey by Gregersen et al (1997), from 400 samples of AP probands and their families, 29.3% of these families had more than one member with AP. Eighty-one families had one or more sibling pairs with AP. From these 81 families, there were three sets of monozygotic twins with AP phenotype and one pair of dizygotic twins discordant for AP. On the other hand, many persons with Williams syndrome had musical ability. Some of
them had AP. AP is unlikely to locate genetically in the Williams region of the brain. It reveals naturally even in persons with Williams syndrome who have no music training in their early childhood. Thus, AP is inherent.

In the survey of 600 musicians by Baharloo et al (1998), a strong relationship between early music training and the AP development was found. Of 92 AP subjects, 49% had first degree relatives with AP and 14% of 520 non-AP subjects had first-degree relatives with AP. AP aggregated in families. Baharloo et al investigated further the siblings who received music training before the age of six. Out of 15 siblings of the AP subjects, nine had AP. Of 23 siblings of the non-AP subjects, only two had AP. Investigating the AP aggregation in families further, Baharloo et al (1998) followed up Ashkenazi Jews. There was a high percentage of Jews who gave their children early music training (Eppstein, 1997; Gonzalez, 1998). Children with AP are more likely to start music at their early age than others. Both inheritance and early learning influence the development of AP. Before the age of six, brains of some individuals can successfully establish new circuits or fine tuning in the pitch perception. Persons with AP genes are more likely to develop AP than others even though all begin the music training at the early age. Therefore, there is AP aggregation in families. Persons who begin early music training will not develop AP if they have no AP phenotype.

Gregersen et al (1999) conducted a survey to 2707 music students. The AP prevalence in AP siblings was 14.1% for the AP probands and 1.7% for the non-AP. The occurrence of AP in parents of the AP probands was 6.5% and in parents of the non-AP probands it was 1.6%. The familial aggregation of AP is common. Many AP subjects reported that their AP appeared in their early childhood when they received music training. They admitted that it was hard to separate the environmental and genetic factors especially when AP students started their music training at around $5.4 \pm 2.8$ years of age. Nevertheless, inheritance plays a significant role, supported with the exposure to music during the critical period.

Baharloo et al (2000) recruited 74 AP persons into a genetic study. All probands had music
training before the age of six. From 113 siblings of 74 probands, 46.9% had music training before six years of age. Of 53 siblings, 47.2% were reported to have AP. Thirteen were tested, 12 had AP. The sibling recurrence rates for AP were 22.6% to 43.5%. Comparing to the AP prevalence of 2.9% in music students and 8.3% in siblings established by Gregersen et al (1999), this result showed a strong familial aggregation. Children with AP are more interested to seek music training at the early age. And AP has “a major-gene effect” (p.758).

Gregersen (2001) collected 600 AP subjects. The rate of AP in their siblings was 25%. AP occurred in 1% of the siblings of non-AP musicians. It proved a strong genetic factor in the AP development too.

Some investigators tried to examine the brain to trace the heredity factor. Keenan et al (2001) used anatomical magnetic resonance images to assess the leftward asymmetry of the planum temporale in AP musicians. It was found that the AP musicians had greater leftward asymmetry of the planum temporale and a smaller right planum temporale compared to non-AP musicians and the non-musicians. But the right planum temporale of the non-AP musicians and non-musicians did not differ significantly from each other. The leftward planum temporale dominance is necessary for the manifestation of AP. Even though early music training is crucial in developing AP, the increased planum temporale asymmetry in AP musicians may be determined in the uterus. The planum temporale has genetic influences. That is why the planum temporale asymmetry in AP musicians is not found in non-AP musicians even with early music training.

Stary (2002) investigated AP development from learning, family inheritance and the brain development for 18 years. The functional magnetic resonance images scanned more activity, development and growth in the left planum template in subjects with the designed music training. But only the subjects from AP families were likely to develop AP and enlarged left planum templates. They performed the pitch production task more correctly than the other groups. The findings support the Heredity Theory.
Besides the above investigations, the Heredity Theory has many supporters in the music field. Slonimsky (1988), a prominent conductor, admitted that AP is innate. It cannot be cultivated. In his family, his aunt, younger brother and he had AP. Welch (1993) expressed the view that AP, like musical talent, had strong genetic factor in Wolfgang Amadeus Mozart. Mozart’s maternal grandparents were musical in addition to his father, sister and sons. Shai Shaham had perfect AP. His father, pianist sister and younger brother also had AP (Evangelista, 1997). De Cogan (1999) mentioned that AP aggregated in his family. Carterette and Kendall (1999) believed that AP, like mathematical talent, is genetic. However, J. T. (2002) claimed that AP results from genes and experience. People with early music training are more likely than others to develop AP, but the trait runs in families. Roy Bogas, a concert pianist, explained how he and his composer brother had AP. They learnt music when they were young. His AP came naturally when he listened to his father playing the piano. It was discovered that when he was three years old he knew the note names. Since his parents and daughter did not have AP, genes may skip generations (Hall, 2002; Shiel, 2002). These cases suggest that AP aggregates in families and the early music training is a supportive factor.

The above findings support the Heredity Theory strongly, but the hereditary theorists failed to explain why there were still AP cases without the family aggregation. Travis (1996) indicated that non-AP musicians had 1.1% parents and 1.3% siblings with AP. Gregersen et al (1997) found that 14% of their non-AP subjects had first degree relatives with AP. Gregersen et al (1999) discovered 1.7% of the non-AP probands had AP siblings. Bachem (1940) admitted that the blind included an exceptionally high percentage of AP possessors. However, there was no evidence of heredity factors in these cases. He proposed on the one hand that AP could be developed if attention to sound was given. This is why, for example, it occurred more in the blind than in seeing people. On the other hand, he insisted that heredity was a prime factor. Without this faculty, no one could develop AP, no matter how hard one practised pitch identification. Brady (1970) “refused to believe that an accident of
birth deprive me (him) of ever learning notes” (p.884) and trained himself to acquire AP successfully. Spender (1980) indicated that 87% of gifted performers had AP. None of them reported siblings or parents having AP. Miyazaki (1988) found out a large proportion of music subjects in his experiments as having AP. An informal test showed that no less than half of music students possessed AP in Japan where the early music training was common. Furthermore, it is difficult to prove AP running in families. Parents with AP would be more likely to provide their children the similar types of musical environment (Levitin, 1998). Gregersen et al (1999), as the heredity theorists themselves, admitted that it is hard to separate the environmental and genetic factors especially when AP children start the music training at the young age. From 122 musically advanced adolescents, Kirchhubbel (2000) did not find evidence to support the Hereditary Theory either.

2.8.2. Learning Theory

In contrast to the Heredity Theory is the Learning Theory. It is based on the postulation that everybody initially has AP and AP can be acquired at any age through training. The accuracy in the pitch identification depends on the amount of practice in the note naming (Meyer, 1899; Mull, 1925; Wedell, 1934; Oakes, 1951; Cuddy, 1968, 1970; Brady, 1970; Corliss, 1973; Eaton & Siegel, 1976).

Meyer (1899) favoured the ideas that everyone has AP. He and his friend trained themselves to learn AP. After 10 months of training, they could identify half of the tones accurately. He proposed that AP could be acquired even though they lost most of the tones acquired due to the lack of practice later.

Mull (1925) trained adults to acquire AP. A mean of 68.5% right judgment out of 12 tones in an octave was recorded. He declared that the average individual can acquire AP if one pays attention to notes.

Wedell (1934) trained adults to acquire AP with a series of 25 tones together or adding up gradually from five tones to 25. The two methods yielded similar results. AP can be learnt and accuracy can be improved through training.
Oakes (1951) summed up that AP depends on how one practises the tone naming. Everyone can develop AP under some right circumstances. Cuddy (1968) trained subjects to identify notes through “A training” and “series training”. Both methods were found to improve subjects’ tone identification. She then theorized that AP judgement can be learnt and improved through training. Brady (1970) employed Cuddy’s (1968) “series training” method to train himself to identify notes. He listened to notes attentively and frequently. He achieved 65% correct answers. He concluded that adults can develop internal referential tones at any age. But the younger it is learned, the better it is. After childhood, it is difficult. His success in acquiring AP supports the Learning Theory strongly.

Corliss (1973) cited an example of an adult who learnt AP effortlessly. He, who had no interest to music, could name the frequencies of any tones by multiplies, sub-multiplies and fractional multiplies of 1000Hz after training. It was his first time to learn to identify tones. It was concluded that AP is innate. Some types of experiences are needed to have it revealed especially in childhood. It may be present in adults though unused. Only a small number of people who are interested in music or acoustics develop it.

Eaton and Siegel (1976) viewed AP as a learnt ability too. They investigated the training methods of Cuddy (1968, 1970, 1971) and Siegel (1972, 1974). It was found that AP could be learnt by non-AP subjects. The improvement was continuous though slow.

AP, according to the learning theorists, is inborn and can be acquired at any age through training. Even though those researchers tried to train themselves or their subjects to acquire AP, only improvements in naming notes were found. Brady (1970) was the only case that reported success. After the lack of practice, his AP declined. He admitted that AP should be learnt in childhood. After that stage, it is difficult. His claim weakens the theory. On the other hand, learning one or a series of notes first were not ways of developing AP. People learn RP instead of AP. The foundation of this theory appears weak.
2.8.3. Unlearning Theory

The Unlearning Theory is based on the assumption that the absolute auditory mechanism is innate to everyone. This theory was first suggested by Abraham (1901, cited in Terhardt & Ward, 1982 and in Crozier, 1997). He pointed out that the general music environment does not favour AP because tunes are sung and played in different keys. AP is trained out of most children because of the movable solfège system. There are two factors in AP development. The first is the appropriate experience which enables AP to develop. The second is the inappropriate experience which hinders AP from developing. Unfortunately, most music experiences are unfavourable to AP since children are taught in RP.

Watt (1917) followed Abraham’s thought that AP is initially universal. Some persons acquire it in their early age and never lose it. They perhaps possess a refined auditory mechanism which is innate to everybody. It makes them maintain the absolute ear in the RP environment. Most people lose it since the absolute ear fails to convert tones into the absolute sense in the relativity of music.

Crozier (1997) trained 12 pre-school children and 12 grade 9 students to acquire A440. He found that the improvement of the young children was greater than that of the adolescents. The young children used AP while adolescents used RP even though RP did not help them in the identification. It was accepted that there must be a favourable environment not to suppress AP as well as for AP to develop. In the music teaching in schools, the movable solfège is used. In the music performance, most woodwind and brass instrument players read transposed scores. Pitch judgments are dominated by RP. These phenomena suppress AP to grow in children.

In order to testify AP as an innate potential, some researchers turned to language for answers. Myers (1907) described that in some Malu songs, there was a return to the beginning high note after the end of each verse in order to continue to the next verse. The natives in the Murray Island could get the tones properly, but how close this note could be approximated was not verified. It was supposed that AP is probably anchored in primitive
people. Stumpf (1911, cited in Petran, 1932) did not agree with Myers that what those primitive people had was well-developed RP rather than AP.

Deutsch (1999) recruited native speakers of two tonal languages, i.e. the Vietnamese and Mandarin. The seven Vietnamese speakers read out ten Vietnamese words on two days. They demonstrated a mean pitch difference of less than 1.1 semitones. The 15 Mandarin speakers read out 12 Mandarin words twice in each session on two days. Half of the subjects demonstrated a mean pitch difference of less than 0.5 semitone and one-third less than 0.25 semitone. It was concluded that the speakers of Vietnamese and Mandarin possess AP and make use of their AP templates in their speech. The trait resulted from their early acquisition of the tonal languages. It was postulated that all people are born with AP and AP for speech and music shares same brain mechanisms (Deutsch, 1999, 2002). Those who speak tonal languages have the chance to develop it while non-tonal language speakers lose it along the development. Her findings supported Abraham's unlearning approach. However, her supposition was not accepted by some scholars. D. Levitin expressed the view that similar experiments needed to be done with the western and other languages to see if such tendency is found or not. Link could not believe that the Chinese people have AP because of the tonal language. Speech should have little relationship to AP as it is used in music (Graham, 1999). Ladd (1999, cited in Brown, 1999) disagreed with Deutsch's conclusion for two reasons. First, if tonal languages require AP, there should be a tonal consistency across speakers. No study has been found on this foundation. Second, European speakers exhibit the same pitch consistency as Deutsch has found in the Vietnamese and Chinese people. Lawton (1999) disagreed with Deutsch's theory too. He, as an English speaker, like anyone else does not vary his pitch of voice from day to day in speech. He could get the E by saying ‘this is the pitch for mee’. Then he could sing any note relative to this E. Hall (1999) queried why the Vietnamese and Mandarin speakers could develop AP by speaking tonal languages, and some westerners could develop AP without speaking any sort of tonal languages. Responding to the Deutsch's experiment,
Saffran and Griepentrog (2001) tested 23 native speakers of Mandarin on AP. It was found that they did not do any better than the chance level. However, another study by Saffran and Griepentrog (2001) supported Deutsch's finding. They played babies a sequence of tones. If the tones were new, babies would listen to them. Otherwise they would be bored. The results found that babies responded to changes in AP while adults did not. Babies can track AP patterns, but show poor RP. This ability diminishes through maturation or in music experiences with the RP dominance. Babies may be born with AP. AP is important in learning languages, especially tonal languages. Once if the language is mastered, AP will be unnecessary. RP development replaces AP. The finding supported the Unlearning Theory.

Deutsch's (1999) proposition was supported further by Braun's (2001) finding. He asked 15 native Dutch speakers to read out 2400 statement sentences. He found that their speech tones were highly correlated with the musical frequencies of A, C, D, E, F and G, pitching the A to A440. It was indicated that AP may provide a basis for speech tones. AP is a "normal trait of the human brain” (p.85). Braun (2002) explained further that the hearing and phonation centre is located in the anterior cingulate cortex.

However, Zatorre (2003) argued that more Asian than western people have AP because of genes rather than speaking tonal languages. Korean and Japanese are not tonal languages and yet a high prevalence rate has been reported among those Asian-Americans who speak English only.

Unfortunately, the Unlearning Theory is based on assumption rather than evidence. Proponents failed to find evidence in music. They turned to seek proof in the language acquisition, but their findings are not persuasive (Ladd, 1999; Lawton, 1999; Hall, 1999).

2.8.4. Early Learning Theory

The early learning theorists, like the learning and unlearning theorists, believed that everyone has the potential to develop AP. However, it should be acquired at the age before six. Preyer (1897, cited in Petran, 1932) appeared to be the first one to suggest teaching
children to name tones at an early age. Besides upholding the Unlearning Theory, Abraham (1901, cited in Terhardt and Ward, 1982 and in Crozier, 1997) pointed out that AP is comparatively easy to develop in children. Copp (1916) picked up this thought and became the first person to formulate the Early Learning Theory. He pointed out that the early music training is crucial in developing AP. AP can only be developed well in children. It would be difficult to acquire after the critical age.

Jeffress (1962) used “imprinting” to explain the Early Learning Theory. Whether a duckling adopts a duck as its next-of-kin or adopts a human being depends on imprinting. Imprinting must be carried out at a very young age. The time range is narrow. People having AP must have the trait in their young age. In homes where parents are not musical, the environment does not favour the trait to grow. Children learn RP at school and AP disappears. If they grow up in musical homes before they go to school, their AP will develop, particularly where parents have AP.

Sergeant (1969) found that the mean age of commencing music learning for AP subjects was 6.7 years. Each additional year of age would bring a progressive decline in the number of AP subjects. Subjects with the lower mean age had better pitch identification than the key identification. All subjects who had higher scores in the key identification than in the pitch identification started their music training after the age of eight. It was concluded that children attend more to pitch at their earlier stage of the music learning. Their attention later shifts to tonality and harmonic features. Sergeant understands the AP acquisition as a childhood mental behaviour. The child's primary experience in musical sound is the infant vocalization, of which the pitch must be an important component. The younger the children play instruments, the more important is the pitch to them. If they learn pitches associated with fixed letter names at the early age when the pitch dominates the auditory perception, they can develop AP.

Sergeant and Roche (1973) asked children of three to six years of age to vocalize melodies. Younger children were discovered to show a better pitch accuracy than older children who
concentrated more on music organizations. This finding supported Sergeant's (1969) study that musicians with early music training would be more likely to possess AP. Only a minority of musicians with AP were found when their music training started at eight years of age or older. AP would completely if the training started after twelve years of age. Miyazaki (1988, 1989, 1990, 1992) discovered that a higher percentage of music students who started music lessons at the young age had AP in Japan. He mentioned that the best time for acquiring AP is three to five years of age. After six years of age, the ability decreases. The use of RP in the primary school music teaching makes it even harder for children to learn AP.

Takeuchi and Hulse (1991, 1993) followed Miyazaki's (1988, 1989, 1990) track and found that AP persons recognize white key tones faster and more correctly than black key tones. Since black key tones are learnt after white keys, AP would develop first for white keys. If children become older and lose the ability before they learn black key tones, they will only develop AP for white keys. The time to lose the ability to acquire AP is the time to learn black-key tones. On the other hand, young children perceive tones individually, especially when they are taught in the fixed-doh system. When they get older, they transfer their attention from single notes to music relationships. As the school music emphasizes tonal relativity, AP declines.

Kirchhubbel (2000), after examining the music development of 122 musically advanced adolescents, found that the group commencing instrumental learning within the ages of three to five got the highest scores in pitch recognition. He proposed that appropriate music training and practice in the critical period is more likely to develop AP. Brown et al (2003) indicated that 67% of their AP subjects commenced their music training at the age of six or younger. They supported the Early Learning Theory.

AP is more commonly found in the autistic than in the general population (Young & Nettbeleck, 1995; Heaton et al, 1998). Firth and Happé (1994) proposed the “Central Coherence Theory” to explain the phenomenon. Autistic persons are good at tasks of local
information, but are poor at those of global generalization. They see parts better than wholes of things, so they develop AP better than RP. Turner (1997) suggested the ‘Executive Deficit Hypothesis’. When autistic children fail to learn things due to their deficit in certain domains, they will approach things which they learn better. They develop AP instead of RP as a result of the awareness to sound. The attention to independent sounds in the autistic is similar to that of the young children. These hypotheses support the ‘Early Learning Theory’ further.

Importantly, it is not only the early learning theorists who favour the Early Learning Theory. Other theorists in the Heredity Theory (Bachem, 1940, 1955; Profita & Bidder, 1988; Gregersen & Kumar, 1996; Travis, 1996; Gregersen et al, 1997; Baharloo et al, 1998; Gregersen et al 1999; Baharloo et al, 2000; Keenan et al, 2001; Stary, 2002), Learning Theory (Brady, 1970), Unlearning Theory (Crozier, 1997) and Inter-behavioural Theory (Neu, 1947; Levitin, 1998; Chang, 2003) favour the early learning in the critical period too.

However, there is still weakness in this theory. The early learning theorists cannot explain why some musicians can develop AP after the critical period. Whipple (1903) mentioned an AP student starting to play the piano at the age of eight. In Sergeant’s (1969) survey, 49.1% of the AP teachers reported to begin music training at a mean age of 7.1 and 33.1% of AP musicians commenced at a mean age of 9.9. Brady (1970), as an adult, trained himself to develop AP successfully. Takeuchi (1989, cited in Takeuchi & Hulse, 1993) reported 15 AP subjects starting music lessons at the age of seven. Takeuchi and Hulse (1991) mentioned one AP subject commencing piano learning at eight years of age and five subjects starting to play instruments between 10 to 16 years of age. Benguerel and Westdal (1991) stated one subject beginning the piano lesson at seven years old. Baharloo et al (1998) reported that 8% of the 161 subjects starting music learning at the age of six to nine, 4% of the 104 subjects starting at the age of nine to twelve and 2.7% of the 112 subjects starting at the age over 12 had AP. Levitin and Zatorre (2003) argued that 33% of Brown et al’s (2003) AP sample commenced music training after six years of age. The
Early Learning Theory is still inadequate to answer the aetiology of AP satisfactorily.

2.8.5. Inter-behavioural Theory

The inter-behavioural theorists do not view AP as an innate potential or a heredity trait, but a learnt skill from the interaction with tones. Neu (1947) considered AP not something inborn, but a result of an individual's reaction to tones. The learning of the first few years marks the basic permanent behaviour. When people get older, they find it more difficult to learn. A better attention to tones facilitates a better achievement in pitch discrimination. That is why AP occurs more in musicians than in the general population. AP is “a fine degree of accuracy of pitch discrimination” (p.264). One may acquire AP through one’s life-time pitch discrimination. Some researchers, however, do not support Neu's supposition. The accuracy in the AP identification and pitch discrimination is positively correlated with AP possessors’ musical experiences (Oakes, 1955; Siegel, 1972). But, AP persons do not show significantly higher discrimination abilities than the non-AP (Siegel, 1972). Sergeant (1969) and Baggaley (1974) discovered that there is no correlation between the accuracy of pitch identification and discrimination among AP possessors. Pitch discrimination and AP are two independent processes. AP is not a final process of pitch discrimination. Tervaniemi et al (1993), using a mismatch negativity examination, discovered that pitch discrimination and naming are two different brain mechanisms. Levitin (1998) argued that it is not the general music training, but the training of tone naming that develops AP. He disagrees with the Learning Theory because most aural trainings only develop RP for children, not AP. He is not satisfied with the Unlearning Theory that assumes all people originally have AP. It is lost due to unlearning and replacement by the RP culture. He does not favour the genetic view because it is impossible to disintegrate the genetic from the environmental influence. AP requires the training in the critical period from birth to the year six. In this period, children must learn to anchor tones to labels. They should abstract pitch from timbre and loudness, and locate tones successfully. In the linguistic aspect, children should learn labels and associate labels
to tones appropriately. Therefore, AP is developed from the training in the pitch identification and labeling task.

Chang (2003) argues that nobody is born with RP or AP. It is a learnt skill because the western scale is a human invention. It has no relationship with the nature. He suggested exposing an individual almost daily to well tuned piano tones from birth. He taught his students to learn AP through learning RP first by memorizing tones like C, E, G, A, the highest or lowest hummed tones, or tones in favourite compositions. AP is developed from the interaction with the tonal identification.

The inter-behavioural theorists viewed AP as an interaction of learners to the tonal environment. They do not admit the inborn nature of AP, but do not attempt to answer how one acquires AP without such potential neither.

2.8.6. Codetta

Stanaway et al (1970) has argued that whether AP is inherited, learned upon early experiences or attained at any age through training has not yet been ‘conclusively proved, and all of them raise difficulties’ (p.231). He claims that researchers have theorized their viewpoints only based on their partial findings and experiences. It is hard for one to theorize AP if it is still ‘a scientific mystery’ (Brown, 1999, p.38). Appropriate theories can be formulated only if a successful technique for teaching AP is developed.

2.9. Processing of AP

How AP develops and is processed in the brain have been controversial topics. Researchers have attempted to find out solutions in the memory, perception, processing and associative strategies of AP.

2.9.1. Possession of Acute Memory for Pitch

Whether AP persons have a better memory for pitch than those of the non-AP is a concern in the development of AP. Van Krevelen (1951) proved that AP possessors had a high acuity in the AP memory, regardless of the recognition or production of tones. Pollack (1952) found that AP subjects could recall significantly more tones at a time than non-AP
subjects. Oakes (1955) pointed out that AP persons may possess a better sensitivity and memory for pitches than non-AP persons. Siegel (1972) and Siegel and Siegel (1972) proposed that AP persons successfully store a number of pitches pointed along the pitch continuum in the long-term memory. They then use this information to identify pitches.

Klein et al (1982, 1984) examined how much working memory an AP person used in the AP processing through the elicitation of P300 in the oddball test. As a result, the non-AP subjects showed standard event-related brain potentials in the auditory and visual responses. The AP subjects showed standard event-related potentials in the visual, but rare or even no potentials in the auditory response. AP persons have brief working memory because they access to permanently stored tones in their long-term memory. They do not need to update the working memory to compare tones. Thus, they, unlike the non-AP persons, do not display a large P300 in responding to rare tonal stimuli in tone identification tasks.

Following a similar experiment by Klein et al (1984), Wayman et al (1992) related AP to the ability to “use a long-term memory of pitch” (p.3527). AP persons can transfer pitches from the short-term to the long-term memory. Similarly, Hantz, et al (1992) discovered that AP persons reduce the amplitude and shorten the latency of P300, or may not elicitation P300 in judging melodic intervals. This is because AP possessors use the long-term memory in pitch identification and discrimination tasks rather than updating the working memory each time. Crummer et al (1994) supposed that non-AP persons must update their working memory by constantly rehearsing a pitch or checking against a reference tone, whereas AP persons need not. However, how pitches are transferred is unknown.

2.9.2. Possession of Auditory Sensitivity

The auditory mechanism consists of the outer ear, middle ear, inner ear, auditory nerve and auditory cortex. Sound is transmitted through the tympanic membrane in the outer ear, the ossicles in the middle ear, the cochlear and hair cells in the inner ear, and the eighth auditory nerve to the auditory cortex in the brain. The cochlea is the most important part of
the ear on the standpoint that it is the main body in processing sound. Different frequencies elicit different maximum responses at different points in the membrane and they are called characteristic frequencies. High frequencies give maximum vibrations near the oval window while low frequencies produce maximum displacements towards the end of the membrane (Moore, 1997). Frequencies are converted to a spatial scale along the membrane (Rasch and Plomp, 1999). This response is mapped with sound waves and this kind of mapping exists in the auditory cortex too (Weinberger, 1999a). The outer hair cells influence the mechanism of the cochlea by producing high sensitivity and sharp tuning. The inner hair cells, transmitting signals to the auditory nerve fibres, transform mechanical movements into neural activities. In the auditory cortex, there are specialized neural detectors to process sound stimuli (Moore, 1997). The neural process is natural whereas the neural response is affected by attention and learning (Weinberger, 1999b).

There are three theories concerning the pitch perception. The first is the ‘Place Theory’. A tonal stimulus elicits a spectral analysis in the inner ear. So, different frequencies excite different places along the basilar membrane and hence evoke the neurons with different characteristic frequencies. Another is the ‘Temporal Theory’, in which the pitch is derived from the time pattern of the neural impulse. The nerve firing would occur from the stimulating wave from and the intervals between successive neural impulses evoked on the basilar membrane. The temporal patterns of nerve spikes are then decoded in some level of the auditory system. The third one is the ‘Pattern Recognition Theory’ which suggests that pitch is derived from a central processor of neural signals of sound. It involves two stages. The first is to analyze the frequency components. The second is to recognize the frequency pattern of the resolved components to determine the pitch (Moore, 1997).

It was believed that AP persons may have an extraordinarily refined hearing, sensory mechanism or auditory memory, especially for overtones (Boggs, 1907; Watt, 1917). They can develop the absolute point of tonal memory in the auditory mechanism. The relativity of pitch exerts little or no influence on them. AP possessors can avoid the relative sense
dominating their absolute ears. Neu (1947) and Lundin (1953) proposed that AP persons have an excellent sensitivity to small differences in frequencies than ordinary individuals. Profita and Bidder (1988) pointed out that AP possessors have a refined pitch memory, perfected by their ‘unusual sensory hypersensitivities’. It is innate and should be practised in the early music learning.

However, Sergeant (1969) demonstrated that AP possessors do not have greater hearing acuity than non-AP possessors in audiometric measurements. On the contrary, the average hearing loss of his AP subjects was slightly higher than those of the non-AP. Two AP subjects had hearing loss over 30dBSPL at levels over 3000Hz. Any harmonics above this level could not be perceived at all.

Wayman et al (1992) evaluated the P300 elicitation of AP possessors on the event-related activity in the response to sine stimuli. AP is the ability to ‘use a long-term memory of pitch’ (p.3527). AP persons can transfer pitches from the short-term to the long-term memory. They use the long-term pitch memory to compare pitch stimuli as they enter the short-term memory. As a result, the P300 latency was the shortest in AP groups compared to RP musicians and non-musicians. The task is the easiest for AP persons as they require less attention and effort. It was concluded that AP possessors have ‘superior auditory sensitivity at cortical level’ (p.3527).

The supposition of hypersensitivity gets support from the hearing characteristics of the SEN. Bachem (1940) pointed out that the blind pay extreme attention to sound since birth. An excellent acoustic faculty is developed. Two musicians had AP declining with increasing deafness, i.e. with weakening auditory sensitivity. Neal (1983) explained that the blind use sound to learn things. They use and are aware of sound more than seeing persons from the age of infancy. J.T. (2000) reported that the blind’s brain areas of vision become devoted to hearing or learning to play musical instruments. Anastasi and Levee (1960) and Mottron et al (1999) suggested that autistic persons with AP have an ‘auditory hypersensitivity’. As a result, they have a higher rate in AP than the general population has.
However, Fujisaki and Kashino (2002) examined eight AP, seven partial-AP, six non-AP musicians and six non-musicians with normal hearing. After a series of experiments in measuring frequency discrimination, tone in notched noise, gap detection and interaural time difference discrimination thresholds, they found no significant differences in frequency, temporal and spatial resolutions among them. It implied that AP persons do not possess particularly sensitive or “good ears” (p.83) for sound. That AP possessors have an “unusual auditory sensitivity” is a belief rather than a fact. AP involves an ability to transfer tones absolutely from the short-term to long-term memory. Whether this tonal long-term memory is developed from a “superior auditory sensitivity” has not yet been proved.

2.9.3. Perception of Tone Qualities

To AP persons, each tone has a unique individual quality from which AP persons can identify tones (von Kries, 1892, cites in Petran, 1932; Whipple, 1903, Boggs, 1907; Révész, 1925; Gough, 1922; Vernon, 1942a; Brammer, 1951; Révész, 1953). Révész (1953) indicated that AP persons identify notes directly from tone individualities from which they anchor tones to letter names. They identify notes as everybody identifies colours. The unique character of tones is the determinant in the recognition.

Tone individuality has been given different names under different researchers. It was called the ‘tone quality” by Boggs (1907), “vocality” by Meyer (1899), “tone body” by Köhler (1915, cited in Révész, 1953), “tonal volume” by Watt (1917), Ogden (1924) and Mursell (1971), “tonal brightness” by Vernon (1942a, b) or “tone chrome” by Bachem (1937, 1955). It refers to the intrinsic property of sound which enables one to identify a tone. The “tone-body” and “tone-chroma” concepts were more widely discussed than others. “Tone-body”, a term originated by Köhler (1915, cited in Révész, 1953), includes brightness, vocality, intensity and volume. Köhler argued that it is the “tone body”, not the pitch itself that enables AP possessors to identify tones. It is different for each note and thus can be recognized by AP possessors. It does not exist in pure tones since pure tones
have no overtones. The AP identification is impossible to unfamiliar timbre since the ‘tone body’ has varied. One may mistake fourths, fifths or octaves because they share similar ‘tone-bodies’. Watt (1917) disagreed with Köhler’s ‘tone-body theory’ that the important attributes should be pitch and tone volume. The theory was later replaced by the ‘tone chroma concept’.

The ideas of ‘tone chroma’ and ‘tone height’ were first introduced by Bachem (1937, 1955). ‘Tone chroma’ refers to ‘the quality common to all musical tones with identical denomination’ (Bachem, 1955, p.1182). For example, ‘C-chroma’ refers to the common qualities of all Cs of different octaves. AP possessors identify tones based on ‘tone chroma’. ‘Tone height’ is the highness of a tone with which one decides which octave the tone should be placed. In the highest and the lowest tones, ‘tone chroma’ disappears while ‘tone height’ still exists. So it is difficult for one to recognize very high and low pitches. Noises have ‘tone height’ but no ‘tone chroma’, and it makes their pitches impossible to identify. Tones from different timbres can be compared and identified as to their ‘chroma’.

In the physical property, the first and the loudest overtone of the fundamental is the octave. The ear can produce ‘harmonic overtones’ in perception. So, there are close relationships among tones of their nearest octaves. ‘Tone height’ is hard to compare. Judgment errors of one to two octaves always occur and octave errors are common in AP processors. Thus, the development of AP involves the memory of ‘tone chroma’ and its association between tactile, visual or semantic elements.

Meyer (1956) disagreed with Bachem’s explanation in the processing of AP. He and his friend practised memorizing ‘tone height’. They could judge tones with ‘tone height’ and the ear failed to produce aural octaves and harmonics. He suggested that the ‘aural harmonics’ cannot be the basics for the ‘tone chroma theory’. Sergeant (1969) determined whether the harmonic quality would affect the pitch identification. Series of notes of various instruments with and without passing notes were played to AP musicians respectively. The identification of notes with passing notes was found easier. This suggests
“tone chroma” plays a role in the AP identification, but it is not a decisive factor. Lockhead and Byrd (1981) and Balzano (1984) viewed ‘tone chroma’ as frequency. They agreed that the tone identification is basically the perception of ‘tone chroma’. Miyazaki (1988) argued that if ‘tone chroma’ can only be perceived by AP persons, it is not a general tonal attribute. It becomes a specific quality that only AP persons can identify absolutely. Semal and Demany (1990) asked non-AP musicians to set the frequencies of pitches in the upper limit of the musical scale. Subjects’ high performance in the tone adjustment fell suddenly at A#7 (i.e. 3729 Hz). They had difficulty in identifying pitches above this level. This supports Bachem’s viewpoint that AP is the recognition of absolute ‘tone chroma’. After this limit, ‘tone chroma’ loses its quality and people fail to identify the tones as a result.

2.9.4. Association of Chromesthesis

Block (1983) defined ‘synaesthesia as the simultaneous response to one stimulus in more than one sensory mode. Chromesthesia, in the form of colour-hearing, is a manifestation of synesthesia in which tone elicits a colour as well as an auditory sensation’ (p. 59). It may be developed at a very young age and carried for a lifetime. Persons with Chromesthesia possess AP (Meyer, 1915; Carroll & Greenberg, 1961; Block, 1983) and persons with AP would be more likely to reflect Chromesthesia because they have unusual sensory hypersensitivities (Radocy & Haack, 1981; Profita & Bidder; 1988).

Abraham (1901, cited in Petran, 1932) stated that only a few respondents had both AP and coloured hearing. Those with coloured hearing mentioned that their AP did not derive from the associated colours. Petran (1932) reported that some AP possessors related tones to colours. Vernon (1977) stated that he had synesthesia in keys. He developed absolute tonality before he developed AP. Costall (1985) reported musicians’ feedback that colour hearing can be used as anchors.

After Costall (1985), no researcher followed up whether some AP persons would develop AP from Chromesthesia or whether AP possessors would relate tones to colours. The
phenomenon is still uncertain.

2.9.5. Establishment of Internal Reference Standards

Some AP possessors may develop an internal pitch reference standard with which the stimulus tone is compared. Chiloff (1930, cited in Petran, 1939) indicated that most AP judgments are done by comparison with a memorized standard tone. Wynn (1971) found that his AP wife had an internal reference tone of A440. After six years, her internal reference tone had drifted to A462 due to the fluctuation in hormone secretions.

Some AP possessors may develop more than one standard (Corliss, 1973; Lockhead 1982; Terhardt & Seewann, 1983) which may not be fixed (Siegel 1972) or may correspond to the chromatic scale (Rakowski 1979).

Eriksen and Hake’s (1957) used ‘Subjective-Standard Hypothesis’ to illustrate the long-term anchoring strategy in the AP identification. Musicians would set up one or two internal tonal standards for comparison, especially to notes in the two ends of the piano scale. Lockhead and Byrd (1981) admitted that it is impossible to tell whether subjects’ judgments are absolute or relative. Many AP subjects reflected that they generated some internal tonal reference standards. AP persons use RP and AP at the same time in the tonal judgment.

Costall (1985) doubted ‘the absoluteness of AP’. He related AP to ‘anchoring’. In AP identification, AP possessors would transform the task into RP, launching the anchor on one or sets of tones. He related that Brady (1970) anchored on C5 in his training. He quoted the memory effect in the AP identification done by Siegel (1972). Subjects’ accuracy dropped significantly without the presented tone for reference. AP musicians tend to compare stimuli to the presented tone. Costall (1985) replicated Siegel's (1972) experiment and found that musicians could transform the presented tone as an anchor even on non-repetitive trials. Musicians’ feedback showed that tones in their vocal ranges, piano scales, colour hearing or tinnitus can be used as anchors. Costall (1985, 1987) observed that AP persons transfer AP into relative judgments. They develop internal reference
standards for themselves. There is no evidence of what Bachem (1937) has called the genuine AP.

Levitin (1994) consented that AP persons evidently internalize pitch references and maintain them in the long-term memory. Possessors employing this strategy can hardly be called genuine AP.

2.9.6. Formulation of a Fixed Scale

A note must carry a tonal relationship in the scale. AP possessors then form a scale in the mind and find the place of the note in the scale when identifying tones (Rupp, 1915, cited in Petran, 1932; Ogden, 1924; Brady, 1970; Corliss, 1973). Brady (1970) trained himself to acquire AP. All notes were remembered according to their positions in the C major scale. When a tone was heard, he formed a scale in mind and placed the tone immediately in the scale. The high-low dimension was used. The scale persisted for an hour. Then, it collapsed especially when a piece of music other than C major was heard. He achieved 65% of right answers. He called his approach the ‘Fixed-Scale Theory’.

Corliss (1973), an AP possessor since childhood, suggested that tones heard were perceived as part of a scale. The position of a tone was recognized immediately through its place in the scale. This character was repeated in every octave, but the identification of the octave was still difficult. Dan (1998) who was an AP possessor had “12 buckets” of tones in his brain. For every tone he heard went into ‘one bucket’.

Whether it was better for subjects to learn to recognize individual tones or a whole scale, Wedell (1934) found no significant difference. Both cases of Brady and Corliss could not be classified as genuine AP because AP and RP were used (Bachem, 1940, 1948, 1955). Miyazaki (1988) explained why some AP persons form the C Major scale in their mind in the identification. It is because AP persons cannot identify all the 12 tones equally well. They recognize four to five notes from which other notes can be related. The C major dominance is resulted from people learning instruments at an early age. They start with the C major scale and the primary triads of C major.
2.9.7. Use of Verbal Encoding Strategy

Jacques-Dalcrose (1921) appeared to be the first one to say that AP is the association of tones to letter names. Siegel (1972, 1974) employed the ‘verbal encoding strategy’ to theorize the association. Siegel (1972, 1974) and Siegel and Siegel (1972) suggested that AP persons can memorize familiar pitches. Letter names, the verbal categorical labels in the western musical scale, are then associated. A verbal labelling system helps to store and use the trait in the memory system. All AP subjects reported that they use the ‘verbal encoding strategy’ to process tones, i.e. the standard letter names. Siegel and Siegel (1977a, b) demonstrated that AP processors process tones absolutely like speech. AP is developed from the categorical perception similar to the phonemic categories of speech. Zakaay et al (1984) found that AP subjects had difficulties in naming tones if they were sung in different note names. One tone can only be associated to one definite name.

Takeuchi and Hulse (1993) discovered that AP persons can retain AP over a long period of time by verbal encoding. AP possessors do not actually memorize pitches, but pitch names. When they identify a tone, they recall the note name first. When they produce a tone, they recall the pitch name again and then reproduce the designated tone. They rejected the supposition of Zatorre and Beckett (1989) that AP possessors use auditory, kinesthetic, visual and verbal codes. They insisted that the verbal code is the only strategy. Levitin (1994) disagreed to Takeuchi and Hulse (1993) that AP includes retaining absolute tonal information and anchoring linguistic labels.

Schlaug et al (1995) used the magnetic resonance imaging to measure the anatomical asymmetry of the planum temporale which is an area of the auditory cortex related to the language processing. It was found that AP musicians showed the strongest leftward position emission asymmetry while non-AP musicians did not differ much from non-musicians. The finding testified that there is pitch naming in the AP identification. Nowak (1995) stated that the leftward asymmetry in the planum temporale includes Wernicke’s area of language. AP is the association of a pitch to a name.
Marin and Perry (1999) used ‘Conditional-Associative Learning’ to indicate the verbal-tonal association. The leftward asymmetry is the result of a smaller right hemisphere planum temporale. The left planum temporale dominance is necessary for the development and manifestation of AP. The verbal encoding is the main processing strategy. Ohnishi and Matsuda (2001) used magnetic resonance imaging to examine the cerebral activity pattern in music listening. The results indicated that AP is associated with the activations of the planum temporale and the left posterior dorsolateral frontal cortex. Even in listening, the note labeling is exercised in AP subjects. Hence, AP involves the verbal-tonal association.

Persons with Williams syndrome have a higher rate of AP than the general population (Lenhoff et al, 2001). Hickok et al (1995) found an exaggerated asymmetry in the posterior supra-temporal region in persons with Williams syndrome. The left planum temporale is relatively greater than the right one. As persons with Williams syndrome demonstrate an exceptional language ability, the planum temporale asymmetry may be associated with language as well as music abilities. This finding also supports the suggestion that AP is related to the verbal coding.

Before 1994, psychologists discovered AP possessors using the verbal labeling in processing AP through observations and self-retrospective reports. After 1995, scientists examined the increased leftward asymmetry of cortex through magnetic resonance imaging. There was strong evidence to show that AP possessors employed verbal associations to tones. But arguments still exist, such as how this process is developed and whether it is the only way to process AP. For example, Miller (1989) found a musical savant having AP before learning note naming. Musical savants usually have limited language which makes such verbal association unlikely to happen.

2.9.8. Use of Multiple Encoding Strategies

AP persons may employ multiple sensory codes in the AP processing. Whipple (1903) described that his subject formed an image of two to five piano keys with eye and hand
movements. Miyazaki (1990) found his subjects associating tones with key locations on
the keyboard too. Petran (1932) reported that some keyboard players form spatial key
positions of a keyboard, violinists imagine hand positions in violin strings, singers exercise
larynx positions and some relate tones to compositions or colours. Costall (1985) reported
musicians’ feedback that tones in their vocal ranges, piano scales, colour hearing or
tinnitus can be used as anchors. Zatorre and Beckett (1989) disagreed with Siegel's (1972,
1974) ‘verbal encoding strategy’. They argued that besides verbal encoding, AP persons
encode cues from the timbre of piano tones, tonal qualities, note names and/or images of
the keyboard or stave.

Zatorre et al (1998) used the positron emission tomography to measure cerebral blood flow
while AP and non-AP musicians were listening to synthetic musical tones and noises. The
most significant difference found in the AP identification was the strong activation of the
left posterior dorsolateral frontal cortex in the AP musicians. This suggests that AP is the
ability to retrieve a pitch and a verbal label spontaneously on demand. In interval
discrimination, both the RP and AP musicians had activation in the left posterior
dorsolateral frontal and right dorsolateral frontal cortex. In addition to the tonal-verbal
association, AP musicians use nonverbal associations as do non-AP musicians. In the
interval-minus-noise condition, the cerebral blood flow of the AP musicians increased
particularly in the left posterior dorsolateral frontal region, the superior parietal region and
the bilateral middle / inferior temporale cortex which involve visual and visual-verbal
associative processing. It is a multimodal processing region. AP musicians thus use
multiple sensory codes.

Some researchers found that their AP subjects use only one encoding strategy of the verbal
code in processing AP. Others found some use more than one sensory codes. The
controversy remains unsettled.

2.9.9. Codetta

Different researchers have examined different AP possessors who may develop different
strategies in the tone identification. The strategies like recalling tones from memory, perceiving tonal individualities and associating tones to verbal labels are associated with AP. Others, like formulating a fixed scale, forming images of instruments with hand positions, exercising larynx positions and relating tones to compositions, keyboards, staves, tinnitus or colours might relate more to RP because comparing tones to internal references can be exercised. Establishing one or many internal reference standards is certainly RP. These skills appear workable in the tonal identification and controversies arise accordingly.

2.10. Training of AP

During the past century, many researchers and musicians tried to explore methods of acquiring AP in order to further understand its nature. Subjects have included children and adults.

2.10.1. Training Attempts with Children

To train children to acquire AP, Boggs (1907) suggested children listen to tones and overtones. Kramer (1916, cited in Petran, 1932) taught children to associate each tone to a colour. When a tone was heard, children were told note names from the colour sensation aroused. No result was recorded. Slonimsky (1988) reported learning do-re-me-fa-so-la-si-do to develop AP in his young childhood. Cogan (1999) related that the boy choristers in Norwich Cathedral were trained to locate a vocal ‘head note’ in the chest. Once it was mastered, they identified and sang other notes relative to the ‘head note’.

Some educators started with the C major scale. Jaques-Dalcroze (1921) guided students to sing and memorize the middle C until they could do it without resorting to the tuning fork. They then memorized the scale of C with fixed solfège by approximating tones from the interval between them. No result was reported. Oura and Eguchi (1982, cited in Miyazak, 1990) started with identifying the C major triad and then followed by other diatonic triads in C major. After the white key notes, black key chords were taught. The training was successful to one child who started the training at four years of age. The training to another one who started at five years of age was unsuccessful because he had developed a tendency
Some started with the A440. Farnsworth (1958) trained himself to recognize the violin A440. He memorized the lowest note that he could hum and took this note as a reference to the A. Later the reference vanished and he could sing the A or tune the A string without any referential tone up to the point of less than an eighth-tone error. Crozier (1997) trained pre-school and Grade 9 students to identify and reproduce A440 within six weeks. They were trained five minutes each day to identify the A440 of the pitch pipe. They discriminated the A from other two tones. The training led to improvement, but the improvement of the pre-school children was greater than that of the adolescents.

Oura and Eguchi (1981) reported that more piano students with AP were found in Japan than in western countries. They started piano instructions at three to four years of age. They identified notes with fixed solfège. They associated flags of different colours to notes and chords. Cohen and Baird (1990) employed this "symbol-and-flag approach" to teach Canadian school-children. The training kept on several weeks. The result was negative.

Chang (2003) suggested exposing babies daily to well-tuned piano tones from birth. Students learnt AP by learning RP first. The C major scale was learnt first, starting with C and then singing tones up or down. After the C diatonic scale, the chromatic scale was learnt. They memorized A440, C, E, G, the highest or lowest notes one could hum, or tones of favourite compositions. They learnt chords by singing thirds, fourths, fifths or octaves. They learnt through sight-singing. They sang with sol-fah names or letter names, and checked with the piano. They had to practise everyday. Most students would succeed to develop AP after a year of practice, but no data was presented. If one stopped practising for a while, the ability disappeared. One needed to learn it all over again.

**2.10.2. Training Attempts with Adults**

The basic technique in training adults to acquire AP is through listening to tonal qualities. Boggs (1907) showed progress in recognizing tones by listening to tones and overtones instead of tonal relationships. Köhler (1915, cited in Neu, 1947) recognized the tone body.
He learnt AP in 14 days, but his judgement had errors of up to seven semitones. Bachem (1940) criticized his accuracy as being far from AP. Paulson et al (1967) trained three mentally retarded teenagers AP by tapping on a lever when they identified the tone of 1455Hz. They gave them candies as a reward. They responded to the test tone but not the others. It was explained that they had developed AP for that particular tone.

Deutsch (1986) suggested a method through listening, singing and thinking of tones. First, find a note at the piano within one's singing voice. Second, listen to this note attentively and sing it. Third, stop singing, but still keep the tension of the vocal cord and remember the tension. After 30 seconds, sing the note and check it at the piano. If wrong, slide it to the right pitch. Fourth, play the same tone and visualize the sound mentally. After 30 seconds, sing the tone and check it. If not right, correct it. One should practise at least five times a day until one can recall it. After acquiring the first tone, one can proceed to memorize the second one. The second tone must not have harmony relationship with the first one, such as the augmented fourth, major seventh or minor ninth. The third one is another inharmonious tone as well. Each tone should be reviewed each day in the reverse order. If one fails to acquire 12 tones, one can memorize one to three tones, and judge other tones with RP. Another exercise is to visualize tones in music.

Another method is to memorize one tone as reference. Seashore (1919) suggested learning one tone and judging other tones with this standard. Hindemith (1969) proposed to acquire the concert A by listening, singing and checking with the A tuning fork. After a hundred trials, one should be able to reproduce the A accurately. One can compare any notes with this internal A. Backus (1969) tried to memorize a pitch with a tuning fork. He carried it around and listened to the tone whenever he had time. But he failed to develop AP after a year’s trial. Bogas told people to take a pitch pipe or tuning fork around for few weeks and keep listening to the same tone to learn AP (Hall, 2002).

Some researchers have suggested learning a series of tones. Meyer (1899) reported that he and his friend identified tones of G3 to D8 on tuning forks and 39 tones on the piano. They
began with 10 tones at an interval of a sixth and gradually increased to 39 tones at an interval of a whole tone. They discontinued the practice further because it was time-consuming. After several years, they lost most memory of what they had acquired. Bachem (1940) criticized this method training as RP instead of AP.

Gough (1922) asked students to memorize a framework of piano notes and judged other tones relatively to the series. After a year, subjects improved from an average error of 5.5 to 4.5 semitones. Bachem (1940) criticized their accuracy far beyond AP. Pollack (1953) suggested developing several standard tones to facilitate comparisons.

Lundin and Allen (1962) designed a 24-button voting board corresponding to the piano keys of a two-octave scale. They pressed a button after listening to a tone. When a right button was pressed, the light of that tone would be on. If it was wrong, the right note would light up. The training lasted for 36 sessions. Subjects who scored 54% to 42% in the pretest got a mean of 95% in the post-test. Takeuchi and Hulse (1993) commented that their improvement might be due to the familiarity to the test tones rather than the improved performance in AP.

Wedell (1934) used frequencies from 50Hz to 7500Hz which were divided equally to provide 5, 9, 13, 27, 25 or 49 stimuli. Subjects had charts to show frequencies. All tones were presented once each day. After three months of training, the average error remained at three semitones in the 49 item series. Bachem (1940) criticized their accuracy as being far from AP.

Many studies have been carried out to demonstrate which method is better, to identify one tone or a series of tones. Mull (1925) asked students to listen to tones of the tonometer attentively and intensively. The after-singing was allowed to enhance memory. One group acquired middle C and improved from 40.4% accurate to 82%. The second group identified seven diatonic notes from F5 to E6 and achieved 5% accurate. The third group identified all chromatic notes from G3 to F#4 and had 62% and 75% accurate. Judgments were sometimes made by comparing neighbouring tones. Bachem (1940) argued that they
developed RP instead of AP.

Cuddy (1968) followed the method designed by Mull (1925). Instead of acquiring middle C, subjects identified A400. After each A, there was a light signal of three seconds. Subjects called “A” within two seconds whenever they recognized an A. They were trained and tested individually three to four times a week. There were totally 16 sessions. As a result, subjects showed improvements of 1/64. In the next training, one group identified A, called “A-training”, and another group identified all tones, called ‘Series-training”. In ‘Series-training’, tones were from F4 to D5. There were eight training sessions. Results showed no significant difference between them.

Cuddy (1970) designed ‘Reference-training” and ‘Series-training” to train subjects to acquire AP. In the ‘Reference-training”, subjects identified three tones of L (low), M (middle) and H (high). But in the ‘Series-training”, they identified all nine tones, i.e. L-, L, L+, M-, M, M+, H-, H and H+. There were two tapes of sine-wave tones in each training session. In Set A, the tones lied within 400 to 2000Hz. The difference between tones was 200mels. In Set B, the tones lied within 500 to 1900Hz. The distance between tones was 100mels. For the ‘Reference-training” tapes, the tones in the second, fifth and seventh ordinal positions were selected as referential tones. The experiment lasted for two weeks with a session a day. Results showed that all groups had improvements without a significant difference.

Cuddy (1971) modified Mull’s (1925) and his own method (1968, 1970) by identifying a triad related to A instead of a tone of A. The references were all Fs, As and Cs from F3 to C7, having totally 12 tones. All series included A4, the basic referential tone. Subjects had eight training sessions. They received the “A-training” first by recognizing each tone as “A4” or “not A4” with feedback. If subjects made mistakes less than three, they proceeded to learn F4-A4-C5. Then they identified all F-A-Cs with octave numbers. As a result, tones based on F-A-C triads and their octaves were identified better than those without these chordal or octave relationships. However, only the subjects’ RP was improved, not AP.
Brady (1970) picked up Cuddy’s (1970) method to train himself AP. He identified the Cs first within A2 to A5. In the beginning, the Cs occurred frequently. The non-C tones were distributed equally. The C was dropped gradually to 1/11 in later sessions. At first, he used RP technique. Later he could identify any Cs without comparisons and could memorize certain tones. All notes were remembered by their positions in the C major scale. He constructed the C major scale in his mind and placed the note in the scale. He eventually achieved 64.9% right answers. Carroll (1975) confirmed his responses as fast and accurate as other AP possessors. But Takeuchi and Hulse (1993) queried that Carroll allowed Brady to play back the responded tone on the second piano. Brady could use RP instead of AP. Brady offered this training to non-AP music students. After completing the C major training, no improvement was found. He concluded up that the task required one to possess a good RP and strenuous practice in listening to and thinking of tones.

Heller and Auerbach (1972) experimented with Cuddy’s (1968) training methods, i.e. “Regular feedback” (called the “Series -training” in Cuddy’s experiment) and “A feedback” (called the “A -training” in Cuddy’s experiment). The training included: a) Familiarization – a tape of ten notes from F4 to D5 in ascending order was presented. Each note was followed by its letter name; and b) Training– four tapes with 80 stimuli of ten notes were presented. The A440 occupied 40%, 30%, 20% and 10% respectively. The “A feedback” group responded whether the tone was “A” or not with feedback. The ‘Regular feedback” group identified all tones with feedback of each tone. As a result, both groups got improvements without a significant difference. But they used the RP more than AP technique.

Other skills in acquiring AP included tuning music instruments frequently (Riemann, 1908, cited in Neu, 1947), matching a colour to each piano tone (Burge, 1986; Rush, 1989) which was found unsuccessful by Rush (1989) and assigning numbers to frequencies (Ward, 1999). Chang (2003) taught adults to learn AP through RP. The technique was similar to those for children mentioned earlier. AP would become difficult to acquire after the age 20
to 30. Even AP persons would lose it around 20 if not maintained. De Vetten (2002) matched the 12 chromatic tones with 12 syllables. They were C=aw, C#=Oh, D=uh, D#=uhn, E=ahh, F=awaa, F#=eh, G=ih, G#=eh, A=ayuh, A#=it, and B=at. After practising for a year, he got 80% to 90% right.

2.10.3. Analysis of Training Attempts

The training methods for children and adults are basically similar. They are: a) relating tones to colours, compositions, symbols or syllabus, solfège or letter names; b) developing anchors on middle C, A440, white key tones, chromatic scale tones, tones within singing voices, the lowest singing tones, the highest singing tones, head tones, C or F major chords, or the C major scale; c) listening to tones of in-tuned pianos, tuning forks, tonometers or pitch pipes; and d) tuning music instruments.

Even though many researchers, for example, Meyer (1899), Boggs (1907), Seashore (1938, 1967), Gough (1922), Mull (1925), Cuddy (1968, 1970, 1971), Brady (1970), Heller and Auerbach (1972), Deutsch (1986), Crozier (1997) and Chang (2003) proposed that every individual has the potential to develop AP and the persistent training in tone identification may help AP to develop, the outcome is not promising. The basic approach focuses on training people to identify a tone, a series of tones, chords, the C major scale or the chromatic scale. The approach can hardly avoid the use of RP. As a matter of fact, RP is encouraged (Seashore, 1919; Jaques-Dalcroze, 1921; Pollack, 1953; Farnsworth, 1958; Hindemith, 1969; Brady, 1970; Deutsch, 1986; Cogan, 1999; Hall, 2002; Chang, 2003). Those claiming to develop AP were in fact RP (Meyer, 1899; Mull, 1925; Wedell, 1934; Bachem, 1940, 1948, 1955). Some tended to develop one or many internal references (Meyer, 1889, Bachem, 1940; Gough, 1922; Lundin & Allen, 1962; Takeuchi & Hulse, 1993; Heller & Auerback, 1972; Cuddy, 1968; Crozier, 1997). Otherwise, the accuracy was beyond AP (Köhler, 1915, cited in Neu, 1947; Gough, 1922; Wedell, 1934; Bachem, 1940; Brady, 1970; Takeuchi & Hulse, 1993), no result was mentioned (Boggs, 1907; Riemann, 1908, cited in Neu, 1947; Kramer, 1916, Petran, 1932; Burge, 1986; Ward, 1999) or the
attempts were unsuccessful (Bachem, 1940; Cohen & Baird, 1990; Rush, 1989). There were a few successful attempts in young children (Abraham, 1901, cited in Petran, 1932; Bonnedik, 1914, cited in Neu, 1947; Komatsec, 1940, cited in Neu, 1947; Oura & Eguchi, 1981) and in an adult (Brady, 1970). However, as Takeuchi and Hulse (1993) have argued there is no evidence showing the AP training being more successful in children than in adults. And successful cases were rare.

2.11. Measurement of AP

An AP test requires subjects to identify musical tones presented singly, separated from each other by a certain time-interval. If the accuracy meets a designed criterion, one is considered to have AP (Petran, 1932; Bachem, 1937, 1940, 1954, 1955; Hartman, 1954; Miyazaki, 1988, 1989, 1990, 1992, 1993, 1995; Takeuchi and Hulse, 1993; Ward, 1999). It is called the passive AP (Petran, 1932). The earliest researchers aimed at exploring the nature of AP through AP tests (Whipple, 1903; Boggs, 1907; Petran, 1932; Wedell, 1934, 1941). It was not until Bachem (1937) that certain criteria for AP were set up to differentiate AP from non-AP or RP. Subsequent investigators basically followed or revised the criteria which he had set up. Recently, Baharloo et al (1998) tried to standardize the AP test and classify AP. But up to the present moment, there is still no agreed standard amongst psychologists and music educators in the measurement of AP (Takeuchi and Hulse, 1993). See Appendix III.1, pp.326-328.

2.11.1. Subjects

Subjects in these studies have mostly been adults. They were university music students or musicians. Only a few have involved children (Zatorre & Beckett, 1989; Miller and Clausen, 1997) or the SEN (Bachem, 1937; Mottron et al, 1999; Lenhoff et al, 2001). The number of AP subjects in experiments was usually small because AP possessors are rare. Only Sergeant (1969b) recruited more than 100, Bachem (1937) recruited 103 and UCGAPS (2003) recruited more than 90 AP subjects. Others recruited one dozen to three dozen (Petran, 1932; van Krevelen, 1951; Profita & Bidder, 1988; Zatorre & Beckett, 1989;
Miller, 1990; Wayman et al, 1992; Miyazaki, 1990, 1993; Miller & Clausen, 1997;
But, most researches had only one to a few AP subjects (Meyer, 1899; Whipple, 1903;
Boggs, 1907; Mull, 1925; Wedell, 1941; Carpenter, 1951; Vernon, 1977; Lockhead & Byrd
1981; Miyazaki, 1989, 1992, 1995; Tervaniemi at al, 1993; Bums & Campbell, 1944;
Hantz et al, 1997; Pantev et al, 1998; Mottron et al, 1999; Lenhoff et al, 2001 etc). See
Appendix III.1, pp.326-328.

2.11.2. Testing Environment

To ensure complete quietness, Wedell (1934) carried out the AP test in a sound-proof room,
and Burns and Campbell (1994) used a sound-proof booth. Otherwise, all were carried out
in quiet rooms without interruption.

2.11.3. Apparatus

In AP tests, the piano was the most frequently used apparatus. Others were the synthesizer,
oscillator, tuning forks, computer, tonometer, resonator, tone variator, pitch pipe, tone
generator, horns, glasses and bells. Music instruments included the organ, electronic piano,
digital piano, violin, cello, flute, clarinet, oboe, guitar, glockenspiel and monochord in
addition to the piano. Out of 48 AP experiments which this researcher has identified in the
literature, the piano was used 22 times (45.8%), the synthesizer was used six times to
assimilate piano tones, and the digital piano was used once to produce piano tones. In total,
 piano tones were used 28 times (58.3%). The second frequently used apparatus was the
synthesizer which was used to produce piano tones on six occasions, pure-tones on five
occasions and violin tones on one occasion, with a total use of 25%. The third apparatus
was the oscillator. It was used to produce pure tones for nine times, with a total use of
18.8%. Others were employed occasionally. See Appendix III.1, pp.326-328.

Even though the piano was the main (Petran, 1932; Lockhead and Byrd, 1981) or the most
practical (Bachem, 1937; Vernon 1977) instrument for AP tests, it was criticized as not
being good enough. It was used for lack of a better choice (Boggs, 1907; von Kries, 1892,
Abraham (1901, cited in Petran, 1932) commented that pressing piano keys produced timbre differences, striking noises and in-harmonic partials which probably made tones easier to identify. If the keys were struck strongly, the relative intensity of the partial might change. This phenomenon made octave identification more difficult, especially in the lowest two octaves. Lockhead and Byrd (1981) also considered the piano to be an unsuitable instrument. When struck, piano strings produced overtones. The harmonics of piano tones were inconstant throughout the whole range. The timbre differences between tones in the lowest two octaves and the rest of tones were marked. The decay characteristics between the highest two octaves and the rest of the piano tones were different. However, Seashore (1938, 1967) and Gregersen (1998) mentioned piano tones as being specifically suitable. A properly maintained and well-regulated grand piano can produce tones consistent across the entire piano range and in various dynamics without striking noises and in-harmonic partials (Tasciotti, 1990, 1991b).

Another question from testing instruments is tuning. Tuning is an important factor contributing to the accuracy of AP identification (Meyer, 1899). Even though a standard pitch of A435 was set by the Paris Academy in 1859 (Tasciotti, 1991a), the standard A had been shifted from 367 to 370Hz (von Kries, 1892, cited in Petran, 1932; Bathloomen, 1925, cited in Petran, 1932; Weinent, 1929, cited in Ward, 1963a; Vernon, 1942a, b). In 1939, the International Standards Organization adopted A440 as the international standard (Backus, 1969; Tasciotti, 1991a). Since then, many orchestras in the United States and all European orchestras still tuned at A442 to A444 (Tasciotti, 1991a). Subjects with different tunings would recognize tones one semitone lower or higher in one direction (Bachem, 1937) and the errors were accepted as right (Dunlap, 1922; Petran, 1932). From the literature in hand, all the test tones used in AP experiments were set to the standard A440, as far as it was mentioned in the papers.

2.11.4. Test Stimuli

Test stimuli were complex tones or pure tones. Complex tones are tones with overtones,
and pure tones are those without. Complex tones are mainly musical tones. As mentioned earlier, piano tones were the most commonly used. They were either produced by upright or grand pianos, or simulated by synthesizers, piano tone generators or digital pianos. Other complex tones which were used occasionally included tones from the keyboard, strings, woodwinds or brass. Tervaniemi et al (1993) and Miller and Clausen (1997) indicated that the test tones should be from the conventional Western scale. The second frequently used tones were pure tones. They were produced from synthesizers, oscillators or tuning forks. Bachem (1940), Kowalsky et al (1997), Howe et al (1998), Gregersen (1998) and Gregersen et al (1999) employed ambient sounds as well. Refer to Appendix III.1, pp.326-328.

There was no restriction in the number of test tones. Bachem (1937) and van Krevelen (1951) used all the 88 piano tones. Since the highest and lowest few notes were difficult to identify, Miyazaki (1989, 1992) used 84, Lockhead and Byrd (1981) used 82, and Klein et al (1984) used 81 tones. Most researchers used the middle registers of the piano scale because they were the easiest to identify among all tones (Meyer, 1899; Whipple, 1903; Petran, 1932; Hartman, 1954; Baggaley, 1974; Balzano, 1984; Miller, 1989; Tervaniemi et al, 1993; Burns & Campbell, 1994; Miller & Clausen, 1997; Zatorre et al, 1998; Marvin & Brinkman, 2000; Keenan et al, 2001). Octave errors were so frequent that subjects were not required to recognize octave designations. Some researchers used few tones restricted to one octave of the middle region (Mull, 1925; Heller & Auerbach, 1972; Siegel, 1974). See Appendix III.1, pp.326-328.

There was no consensus over the duration of test tones. Meyer-Eppler (1954) figured out the duration threshold for some tones. For the fundamental frequency of 100Hz, the threshold of duration is 45 milliseconds, at 200Hz it is 30 milliseconds, and then at 500Hz 26 milliseconds, at 1000Hz 26 milliseconds, at 2000Hz 13 milliseconds, 3000Hz 14 milliseconds, at 4000 Hz 14 milliseconds, at 5000Hz 18 milliseconds. Butler (1992) questioned the applicability of these minimal durations. They should sound longer to be
perceived as musical tones. Seashore (1967) pointed out that pitch would vary with
different durations. Ward (1999) stated that the slight change in duration would not be
perceived. Gough (1922, cited in Petran, 1932) sounded each test tone several times for ten
seconds. Wedell (1934) held tones for five seconds. Baggaley (1974) held until they faded
away. Bachem (1937) argued that test tones should not be long enough for RP. Van
Krevelen (1951), Heller and Auerbach (1972), Balzano (1984), Tervaniemi et al (1993),
Miller and Clausen (1997), Baharloo et al (1998), Marvin and Brinkman (2000) and
held for two seconds. Miyazaki (1989) held for 0.8 seconds. Zatorre & Beckett (1989),
tones holding for one to two seconds appear to be more frequent. See Appendix III.1,
pp.326-328.

Intensity may be an influential factor in the AP judgment (Lewis, 1937; Mursell, 1971).
Pitch varies with intensities (Seashore, 1967). Fletcher (1934) discovered that pure tones
below 2KHz become lower and those above 2KHz become higher when it is intensified.
But a slight change would not be perceived (Ward, 1999). Bachem (1937, 1954) left
subjects to decide the intensity of test tones. Hartman (1954) and Heller and Auerbach
(1972) controlled tones in 50dBSPL, Burns and Campbell (1994) in 70dBSPL, Cuddy
83dBSPL. The intensities of 50dBSPL to 83dBSPL are comfortable hearing levels. It is a
common practice to present tones in a comfortable audible intensity. Refer to Appendix
III.1, pp.326-328.

Randomization is commonly used to present test tones. This may sometimes result in
adjacent tones with minor or major seconds. These small jumps may lead to RP judgments
if inter-stimulus intervals are short. Most researchers wanted to rule out this bias. Wedell
(1934), van Krevelen (1951) and Marvin and Brinkman (2000) arranged no consecutive

To avoid subjects comparing to previous test tones, the inter-stimulus interval is another feature to notice. Concerning the intervallic distraction, Mull (1925) introduced a short period of auditory intervention. Petran (1932) reported that Stumpf used conversations, Abraham used conversation and unusual modulations in the piano, Révész used meaningless sound combinations, and Weinent asked subjects to relax for some hours. Hartman (1954) used intervening noises of six seconds and silence of one second. Balzano (1984) organized a two-second glissando from 0Hz to 5500Hz. Marvin and Brinkman (2000) designed 12 one-and-half-second distraction tones. Takeuchi and Hulse (1993) reported that introducing interfering materials is an effective way of erasing the memory of former test tones. Van Krevelen (1951) permitted an interval long enough for subjects to write down answers. Brady (1970) tested himself a note a day when he woke up in the morning before hearing any tones. Seashore (1967) agreed with what Brady had done. But Hall (1982) commented that it is difficult to achieve. Bachem (1954) found that non-AP persons are difficult, strenuous and inaccurate in memorizing tones over 15 seconds. The interval should be at least 15 seconds to avoid RP. Brown (1958) and Peterson and Peterson (1959) found out that nearly no information can be recalled after a retention interval of 18 seconds if a distractor task is used to prevent rehearsal. Hall (1982)
suggested that the interval must be five to 30 minutes. Nevertheless, most investigators
designed the inter-stimulus interval from 1/4 to 15 seconds. Lockhead and Byrd (1981)
Miyazaki (1990) 5 seconds, Zatorre and Beckett (1989) and Hantz et al (1997) 6 seconds,
Wayman et al (1992) and Crummer et al (1994) 8 seconds, Wedell (1934), Cuddy (1968),
Heller & Auerbach (1972) and Veron (1977) 10 seconds. See Appendix III.1, pp.326-328.

2.11.5. Testing Method

All AP tests were conducted individually, except the one in Cuddy’s study (1968). Tests
were carried out in a group of two to three. The testing method for AP was straightforward.
When the piano was used live, the subject stood close with the back against the piano.
When a key was struck, the subject responded (Petran, 1932; Bachem, 1937; Brady, 1970;
Lockhead & Byrd, 1981). If the synthesizer, oscillator, tuning fork, tonometer, tone variator,
tone generator, strings, woodwinds, brass instruments or ambient sounding objects were
used live, sound was generated behind the subject (Mull, 1925; Bachem, 1937; Carpenter,
1951; Hartman, 1954). If the test stimuli were recorded, they were presented either free
field through loudspeakers (Cuddy, 1968; Zatorre & Beckett 1989; Miyazaki, 1989, 1990;
Miller & Clausen, 1997; Marvin & Brinkman, 2000) or binaurally through earphones or
headphones (van Krevelen, 1951; Hartman, 1954; Wayman et al, 1992; Miller & Clausen,
1997).

Subjects responded by: a) naming notes (Petran, 1932; van Krevelen, 1951; Miller &
Clausen, 1997; Miller & Clausen, 1997); b) pointing at keys of keyboard charts (Gough,
1922; Bartholomew, 1925, cited in Petran, 1932; Wedell, 1934); c) pointing at keys of the
same piano of the experimenter without sound (Bachem, 1937) or with sound (Lockhead &
Byrd, 1981); d) pointing at keys of a second piano (Carroll, 1975; Miyazaki, 1990), a toy
piano with a keyboard of one octave (Abraham, 1901, cited in Petran, 1932) or a Vergil
Clavier without sound (Baird, 1917); e) writing down note and octave names (Carpenter,
1951; Cuddy 1968; Wayman et al, 1992; Tervaniemi et al, 1993; Crummer et al, 1994) or note names only on paper (Baggaley, 1974; Heller & Auerbach, 1972; Hantz et al, 1997; Baharloo et al, 1998; Keenan et al, 2001); f) notating notes on the manuscript paper (Vernon, 1977; Zatorre & Beckett, 1989; Mottron et al, 1999); or g) circling choices on a self-designed chart (Hartman, 1954). If the test was done through the computer, responses might be given by typing in letter names through the computer keyboard (Balzano, 1984), pressing keys on a digital keyboard (Miyazaki, 1989), pressing on a self-designed “on-screen pitch class wheel” (Marvin & Brinkman, 2000) or a self-designed keyboard diagram on the desktop (UCGAPS, 2003).

In giving answers, subjects wrote down note names as well as octave designations whether octave errors were counted as mistakes (Tervaniemi et al, 1993) or not (Bachem, 1937; Carpenter, 1951; Brady, 1970; Lockhead & Byrd, 1981; Zatorre & Beckett, 1989; Wayman et al, 1992; Crummer et al, 1994). Subjects might be asked to write down note names only because octave errors were ignored (Stumpf, 1883, 1890, cited in Petran, 1932; Heller & Auerbach, 1972; Baggaley, 1974; Miyazaki, 1990; Hantz et al, 1997; Miller & Clausen, 1997; Baharloo et al, 1998; Marvin & Brinkman, 2000; Keenan et al, 2001; UCGAPS, 2003).

Subjects responded to one test tone after another. Normally, no feedback was given except in Lockhead’s and Byrd’s (1981) experiment. Stimulus tones were replayed on the piano or written answers were offered by the experimenter. And the next test tone came after the interval of only a quarter second. Hall (1982) argued that this method was not measuring AP but RP, except the first one of each block. In fact, no feedback given was insisted by all other researchers (e.g. Crummer et al, 1994; Levitin, 1998; Baharloo et al, 1998; Marvin and Brinkman, 2000; Keenan et al, 2001).

Subjects were expected to give note names directly, immediately and certainly to test tones. The AP judgment distinguished from the RP was by the speed. AP persons named note names immediately, even though they judged octave designations one or two octaves
higher or lower hesitatively (Baird, 1917; Mull, 1925; Bachem, 1937, 1955; Brady, 1970; Carroll, 1975; Miyazaki, 1988, 1989, 1990; Levitin, 1998; Marvin & Brinkman 2000). Miyazaki (1989) found that the mean response time to synthesized complex tone was 1.611 seconds. Marvin and Brinkman (2000) recorded 2.15 seconds. Right judgments were made more quickly and directly than the less accurate or certain ones (Boggs, 1907; Petran, 1932; Bachem, 1937, 1955; Miller & Clausen, 1997; Miyazaki, 1990, 1993). See Appendix III.1, pp.32-328.

2.11.6. Degree of Precision

AP possessors identify tones with different degrees of accuracy. A high accuracy is rare (Shuter-Dyson & Gabriel, 1981). In tests with piano tones ignoring octave errors, the accuracy was 91.6% (Miyazaki, 1989) and 90% to 100% (Miyazaki, 1992), using 84 tones from C1-B7. Klein et al (1984) reported 60.63% accuracy in 81 tones from C2-C8. Wayman et al (1992) reported 66.75% to 99.32% in 73 tones from C1-C7. Vernon (1977) recorded 87.5% in 64 tones from A1-C7 70% to 90% accuracy was recorded by Miyazaki, (1990, 1995) and 40% to 90% (Miyazaki, 1993) in 60 tones from C2-B6. Only seven possessors were reported to identify 88 tones (Bachem, 1937). When octave errors were counted, the accuracy was 42.87% (Klein et al, 1984). In the mean error of semitones, Wedell (1941) found errors from 0.5 to four semitones. The mean error for AP was allowed at most a semitone (Meyer, 1899; Mull, 1925; Seashore, 1919, 1938, 1967; Zatorre et al, 1998). The accuracy might be influenced by setting of a standard pitch, with the deviation of 6% to 7% (Révész, 1953), by aging (Vernon, 1977), or by physical and mental stress on the auditory mechanism (Wynn, 1992). If shifting happened, one or two semitones higher or lower in one direction were counted as correct (Bachem, 1937; Seashore, 1919, 1938, 1967; Vernon, 1977; Wynn, 1992). See Appendix III.1, pp.326-328.

AP possessors identify different registers with different accuracy. The greatest precision occurs in the middle region (Stumpf, 1883, 1890, 1901 cited in Petran, 1932; von Kries, 1892, cited in Petran, 1932; Whipple, 1903; Révész, 1913, cited in Petran, 1932; Baird,
Miyazaki (1989) found that the most correct responses for piano tones and complex tones were C4 to B6 and C3 to B5 respectively. The middle region is the most often used and heard (Stumpf, 1883, 1901, cited in Petran, 1932; Révész, 1913, cited in Petran, 1932; Miyazaki, 1989) and the most definitely associated with letter names among all tones (Révész, 1913, cited in Petran, 1932). However, Meyer (1899) did not find his AP subjects having a better judgment in the middle register. Boggs (1907) admitted that this regional superiority affected the accuracy of some of his subjects, but not all. Stumpf (1883, 1890, 1901, cited in Petran, 1932) found that the regional superiority depends on instruments. A double bass player judges lower tones better than higher tones, a piano player judges the middle register better than others, and a violinist identifies the upper range better than the lower one.

The highest and lowest extremes of the piano scale are the most difficult to judge among all piano registers. The tone quality of tones above 4000Hz (C8) become unclear to human ears and the judgment can be very wrong (Abraham 1901, cited in Ward, 1963b; Baird, 1917; Bachem, 1948, 1954; Carpenter, 1951; Ward, 1954, 1963b; Corliss, 1973; Ohgushi & Hatoh, 1992). The auditory neurons fail to fire at tones higher than 4000Hz (Corliss, 1973). The frequency discrimination ability may decline even above 3000Hz (G7) (Burns and Feth, 1983). Semal and Demany (1990) suggested the 3729Hz (Bb7) being the discrimination limit.

AP possessors identify white key tones better than black key tones (Whipple, 1903; Boggs, 1907; Baird, 1917; Petran, 1932; Sergeant, 1969; Miyazaki, 1988, 1989, 1990; Takeuchi & Hulse, 1991, 1993; Miller & Clausen, 1997; Mottron et al, 1999; Ward, 1999; Marvin & Brinkman, 2000). Miyazaki (1990) found out that G was the most correctly recognized tones, followed by C, A, D, E, F and other black key notes. The mean correct responses to white key tones were 96.1% and 89.2% for black keys. Takeuchi and Hulse (1991, 1993) found a mean of 90% correct for white key tones while 75% for black key tones. Miller
and Clausen (1997) found a higher accuracy for white key notes, both for children and adults, and across the piano tones and pure tones. For children, the accuracy in order was C, A, A#, E, D, C#, F, B, G#, D#, G and F#. For adults, G, B, C, D, E, F, G#, F#, A, A#, D# and C#. Both groups identified white key tones better than black key tones. But Ward (1999) argued that it might be due to listeners giving white key note responses more than black key notes in experiments. The percentage of having right white key notes answers was proportionately higher. Marvin and Brinkman (2000) did not find any significant difference in the accuracy of identifying black and white key tones.

AP persons identify white key tones faster than black keys too (Baird, 1917; Miyazaki, 1988, 1989, 1990; Takeuchi & Hulse, 1991, 1993; Ward, 1999; Marvin & Brinkman, 2000). Miyazaki (1989, 1990) found out the mean response time to white key tones was 1.575 second, and 1.662 second for black key tones. The response for white key tones is significantly shorter than that of the black key tones. One might argue that when subjects were asked to respond by pressing piano keys, black keys were further to reach (Ward, 1999). In AP tests, musicians found it easier to identify and recall white key tones than black key tones. White key notes had single labels, whereas black key notes had sharps and flats (Marvin & Brinkman, 2000). In order to solve the query, Miyazaki (1990) asked subjects to respond through a computer keyboard. White and black key tones had the same distance to them. Similar results were found.

Boggs (1907) and Marvin and Brinkman (2000) related the white key superiority to the confusion of names rather than the sound. The white keys have their own names while the black keys do not. Sergeant (1969) and Miyazaki (1988, 1989, 1990) related it to the music learning in the early years. Piano instruction begins with the diatonic scale of C major and thus white key notes are more frequently heard and better learned. When they learn black key tones, the efficiency in AP has decreased. Similarly, Takeuchi and Hulse (1991, 1993) referred it to the greater exposure to white key notes in music in general. Musicians develop AP for white key prior to black key tones. They identify white key tones directly.
while they name black keys relative to neighbouring white keys. Take C#/Db as an example. They think whether the note is C or D. If not, is it higher or lower? Then, they make a final decision. Miller and Clausen (1997) related it to cognitive development. Even though AP appears early in childhood, its manifestation is better in adults than in children. There is an increase in accuracy with age. The white key tones’ superiority is due to the greater exposure of subjects to the white key tones compared to the black key tones in the western music culture as they grow up. In improving accuracy, Ward (1999) proposed a ‘fixed solfèggio’ in which every white and black key note is assigned to an independent label, such as ‘do, key, re, guy, mi, fa, nay, sol, bee, la, pay, ti, do’ (p.275).

2.11.7. Common Errors

The octave error, among all tonal identification mistakes, is one that AP possessors make most (Stumpf, 1883, 1990, cited in Petran, 1932; Baird, 1917; Bachem, 1937; Révész, 1953; Ward, 1963a, b; Carroll, 1975; Lockhead & Byrd, 1981; Ward & Burns, 1982; Demany & Armand, 1984; Costall, 1985; Miyazaki, 1989). Octave error means that the name of a note is recognised, but assigned to a wrong octave (Takeuchi and Hulse, 1993). AP persons can judge the pitch classes directly and fast, but only estimate the pitch height like RP persons (Bachem, 1937; Takeuchi and Hulse, 1993). Octave errors are so common that they are seldom counted as mistakes (Bachem, 1937, 1954; Zatorre & Beckett, 1989; Takeuchi and Hulse, 1993; Marvin & Brinkman, 2000; Keenan et al, 2001; Baharloo et al, 1998, 2000).

However, Meyer (1899) did not find any octave errors in his subject or himself. Whipple (1903) found this feature too, but his subject was tested with tones in two octaves only. Köhler (1915, cited in Neu, 1947) mentioned that neither his subjects nor he made octave errors due to different tonal brightness. Lockhead and Byrd (1981) and Riker (1946) discovered AP persons making fewer octave errors with piano tones than with pure tones. Mottron et al (1999) did not find any octave errors in QC who was a musical savant.

There are three theories explaining the commonness of octave errors (Demany and Armand,
The first one is the “Musical Acculturation Hypothesis”. Stumpf (1883, 1890, cited in Petran, 1932) suggested that octave errors originate from ignorance and miscomprehension of pitch registers. Ward and Burns (1982) stated that students are taught tones of various octaves being similar. Tones beyond an octave are discriminated like ones in the octave. Takeuchi and Hulse (1993) reported that musicians have no system to assign octaves. Octave designations should be included in naming. The second is the “Associative Learning Hypothesis”. Stumpf (1883, 1890, cited in Petran, 1932) and Baird (1917) explained that the overtones of tones in different octaves are similar to each other. They are easily confused especially when they have same letter names without octave numbers. Bachem (1937), Davis et al (1951), Terhardt (1974), Ward (1963a, b), and Ward and Burns (1982) stated that the octave periodicity of musical tones divides scales into octaves. All the harmonics of a fundamental are also the harmonics of its sub-octave. They have a strong sensory similarity. AP persons make octave errors because they confuse the overtones with fundamentals. The third is the “Neural Coding Hypothesis”, in which the inter-spike intervals of tones in the auditory nerve are similar with those an octave above (Ohgushi, 1983). Demany and Armand (1984) tested the sensitivity of three-month-old infants to tone height and chroma. Even though they can detect a pitch shift by an octave, they are more sensitive to pitch shifts of other intervals. It was concluded that the ear is less efficient in detecting octaves.

Next to octave errors, AP possessors often make semitone errors, or errors of an octave and a semitone (Bachem, 1937). Thirds and sixth, and fourth and fifth errors are less frequent because they have more tonal individuality (Ogden, 1924; Bachem, 1937). Other errors are rare (Bachem, 1937).

2.11.8. Influence of Timbre on Precision

The timbre of instruments may affect AP judgements. Takeuchi and Hulse (1993) defined timbre as “the perceived acoustic quality of sound” (p.350). It is the unique sound produced by a music instrument. It was generally believed that the easiest tones to judge
are from the timbre one is familiar with most (Stumpf, cited in Petran, 1932; Meyer, 1899; Whipple, 1903; Baird, 1917; Petran, 1932; Riker, 1946; Takeuchi & Hulse, 1993; Hantz et al, 1997; Marvin & Brinkman, 2000). Seashore (1919) commented that a rich tone is easier to identify than a pure tone. Brammer (1951) mentioned that AP violinists identified violin tones more correctly than clarinet tones. Levitin (1996, cited in Levitin, 1998) found that flute and violin players sometimes identified sine tones better than piano tones. But, Bachem (1937) found no timbral influence in his subjects. They identified tones of different timbres with the same accuracy as tested by the piano.

Sergeant (1969) explored the factors of timbral influences on AP, in which the piano, clarinet, violin, glockenspiel, monochord, guitar, organ, flute, cello and oboe were used. No significant relationship was found between the ease of tonal identification and timbre. Sergeant (1969) conducted another test to more than 100 AP musicians. It was found that they identified tones better on familiar timbres. They identified tones more accurately from instruments which they played in their early childhood, generally the first learnt, even from the instruments that they no longer played. If they had changed to other instruments, they identified tones better from the first instruments rather than from those of greater importance to them. Familiarity is not a major factor, but the instrument which one first learns in one's young age. Pitch is learnt very early and is learnt through playing instruments.

Miyazaki (1989) examined the effect of timbre on AP, in which piano, synthesized complex and pure tones were employed. It was found that piano tones were identified most accurately, followed by complex and pure tones. Subjects started piano learning within three to five years old and acquired AP through learning the piano. They developed sensitivity to the piano timbre at their young age. Synthesized complex tones were less correctly identified because those tones were unfamiliar and unnatural to them. The familiarity of timbre is a factor, but only an auxiliary one. AP persons memorize pitch class, not timbre.
Researchers listed instruments according to their difficulty levels of identification. Von Kries (1892, cited in Neu, 1947) listed, from the easiest to the most difficult, the piano, strings, woodwinds, voice, whistling, tuning-forks and bells. The order might not reflect familiarity. Whipple (1903) mentioned that his subject identified tones more correctly on her own piano than on another one. He listed the piano, violin, other music instruments and voices. Baird (1917) ranked the piano, tuning forks, four organ stops (diapason, reed, string and flute), flute and clarinet. Petran (1932) ranked the piano, violin, woodwinds, organ, voice, tuning forks and pipes, bells, glass and voice. The rank depended on the familiarity of timbre and the complexity of the waveform. Among all instruments, the piano tone is found to be the easiest to judge (von Kries, 1892, cited in Neu, 1947; Whipple, 1903; Boggs, 1907; Baird, 1917; Petran, 1932; Bachem, 1937; Wedell, 1941; Riker, 1946; Baggaley, 1974; Rakowski, 1978; Lockhead and Byrd, 1981; Balzano, 1984; Rakowski and Morawska-Bungeler, 1987; Peterson et al, 1959; Miyazaki, 1989). The piano timbre is identified faster than strings by music students, including string players. This may be due to the fact that the piano is often used in classroom music lessons (Marvin and Brinkman, 2000).

2.11.9. Influence of Physical Conditions on Precision

AP accuracy may be influenced by attention, being disturbed, fatigue (Boggs, 1907), increasing deafness (Bachem, 1940), fatigue, illness, absence from music for a long period of time (Sergeant, 1969), diseases, depression, anxiety, stress (Wynn, 1971, 1972) and lack of practice for a while (Chang, 2003). Vernon (1977) found that he heard tones one to two semitones higher due to aging.

Wynn (1971, 1972) discovered that his male subject’s AP fluctuated in a period of 20 days. This suggested a connection with hormones. Wynn (1971, 1972, 1973, 1992) found that the production of A440 by his female subjects fluctuated from 436 Hz to 460 Hz due to menstrual cycles. The menstruation influences the electrical activity in the auditory nervous system. It indicates a change in hormone levels too. But he did not find AP
drifting significantly with age (Wynn, 1992).

2.11.10. Codetta

The standards for the AP achievement and testing method still vary across AP experiments. The basic standard for the AP measurement has not yet been established (Takeuchi & Hulse, 1993). There are still many controversial aspects, such as the testing instrument, stimuli, procedure, answering method, scoring system and the lowest limit of AP. It was hoped that a standardized AP test could be set up.

2.12. Introspection of AP

In addition to the quantitative data on the AP test, investigators have always tried to get more information through subjects’ introspective reports (Mull, 1925; Corliss, 1973; Veron, 1977; Benguerel & Westdal, 1991; Tervaniemi et al, 1993), interviews (Whipple, 1903; Boggs, 1907; Bachem, 1940; Profita & Bidder, 1988), questionnaires (van Krevelen, 1951; Profita & Bidder, 1988; Miyazaki, 1988, 1989, 1990, 1992; Takeuchi, 1989, 1991; UCGAPS, 2003) and surveys (Sergeant, 1969; Baharloo et al, 1998; Gregersen et al, 1999). Data, such as sex, age, music achievement, age of commencing music training, tone identification training, ways of identifying tones, time to reveal AP and the music background of family members were gathered.

2.12.1. Sex Difference

Valentiner (1913) found 2.5% of the females out of 17.7% of music lovers possessed AP. Stumpf (1883, 1890, cited in Petran, 1932) discovered fewer women than men having AP. Profita and Bidder (1988) found 13 (68.4%) women out of 19 subjects having AP. However, Bartholomew (1925, cited in Petran, 1932), Weinent (1929, cited in Petran, 1932), Petran (1932), Sergeant (1969) and Baharloo et al (1998) found no gender difference.

2.12.2. Onset Age of Music Education

Musicians with AP usually started their music training at six years of age or younger (Boggs, 1907; Bachem, 1940; van Krevelen, 1951; Sergeant, 1969; Corliss, 1973 Vernon,

Welleck (1963, cited in Miyazaki, 1988) found a correlation of .80 between early music training and AP. Sergeant (1969) recorded that 58.8% of AP subjects started music training at the mean age of 6.7, while the non-AP at 9.9. The earlier musicians started music learning, the higher was the number of AP possessors. Miyazaki (1988) reported that seven (70%) AP students out of ten subjects started piano lessons at three to five years of age. In the second experiment, 14 (35.9%) AP subjects out of 39 music students had started piano lessons at three to five years of age, with the mean age of 4.1.

Baharloo et al (1998) reported from 612 respondents that 40% (29 out of 72) of AP subjects started music training below the age of four, 27% (43 of 160) between four to six, 8% (13 of 161) between six to nine, 4% (4 of 104) between nine to twelve, and 2.7% (i.e. 3 of 112) over 12. After a survey of 2707 music students, Gregersen et al (1999) reported that the mean age of AP students at the beginning of the music training was 5.4 ± 2.8 years, while for the non-AP was 7.9 ± 3.2 years. Baharloo et al (2000) found that from 113 siblings out of 41 probands, 53 (46.9%) had the music training under six years of age and 25 (47.2%) of these 53 siblings had AP. From the rest of 60 (53.1%) siblings who did not receive the music training under six years of age, only one (1.7%) was reported to have AP. These findings reflect the correlation between young age and the AP development.

2.12.3. Time to Reveal AP

Bachem (1940) reported that five musical prodigies had early musical training, starting between two to five years old. They demonstrated AP within two weeks to half a year of
learning. One exhibited AP at one year old. Profita and Bidder (1988) pointed out that 25% of subjects recognized the trait by the age of five and 90% by ten. Tervaniemi et al (1993) reported that their eight AP subjects noticed AP at the mean age of nine years. It was commonly claimed that AP develops at an early age.

2.12.4. Familial Aggregation

From 1556 returned questionnaires, Sergeant (1969) did not find any data to support the hereditary factor of AP. However, many researchers found different results. Boggs (1907) reported that all his 13 subjects considered their AP an inherited ability. Bachem (1940), after interviewing 103 AP persons, reported 41(39.8%) having AP relatives. One third considered their AP inborn.

From 19 AP subjects and their 16 AP first-degree relatives, Profita and Bidder (1988) discovered the parent-to-child inheritance. From 612 respondents, Baharloo et al (1998) recorded that 15% (92 out of 612) reported having AP, 48% (44 out of 92) had first degree relatives with AP and 14% (72 out of 520) of non-AP subjects had first degree relatives with AP. These findings suggested that AP aggregates in families. Of 15 siblings of AP respondents, nine (60%) had AP. Of 23 siblings of non-AP respondents, only two (8.7%) had AP. A genetic factor in AP was indicated.

From a survey to 2707 music students, Gregersen et al (1999) reported that the AP recurrence rate in siblings was 14.1% for AP probands and 1.7% for non-AP probands. The AP occurrence in parents of AP probands was 6.5% and 1.6% for non-AP probands. However, early music exposure and AP phenotypes cannot be separated. The occurrence of AP in children increases their interest in receiving music training at an early age. Many subjects revealed AP in their very early childhood. More AP persons are found in Japan. Certain music training, like the Yamaha class, seems to help AP develop in children. On the other hand, there may be a higher prevalence of AP genes in Asian populations.

Baharloo et al (2000) reported that from 41 AP-1 subjects, the recurrence of AP-1 in the siblings of AP-1 probands was 22.6 to 43.5%. The early music training was familial too.
Among 113 siblings, 53 (46.9%) had early music training. Among 625 students, 139 (22.2%) had early music training. Children with AP are more likely to seek music training at their early age. The University of California Genetics of AP Study (2003) had been conducted since 1997. Up to 29th January 2002, Shiels (2002) reported that 900 people took the AP test. Ten percent had AP. The siblings of AP persons were 15 times more likely to demonstrate with AP than persons with the early music training from non-AP parents. All the findings suggested that AP aggregates in families and has a genetic factor.

2.12.5. Tone Identification Training

The training on the tone identification appears to be a crucial factor in acquiring AP. Nevertheless, through the subjects’ music history, Boggs (1907) did not find his 13 AP subjects having such training. Levitin (1998) argued that AP possessors must have systematic training in the pitch identification with labels at the young age. Most AP possessors may not even recall this. Other researchers failed to mention whether their subjects had such trainings or not.

2.12.6. Codetta

Through surveys, investigators can get valuable data to explain various aspects of AP, like its aetiology, learning process and brain processing. Nevertheless, they focused only on the familial aggregation and the early learning of AP. Other parameters were neglected.

2.13. Value of AP

It was certainly accepted that AP can help to identify and produce tones without reference. Other values are still controversial.

2.13.1. Pros

Some researchers have favoured the development AP. It is considered as a musical talent (Koing, 1925, cited in Petran, 1932; Mjen, 1926, cited in Farnsworth, 1958; Brown, 1999). It is a part of musicality (Stumpf, 1890, cited in Petran, 1932; Sacks, 1995; Baharloo et al, 1998). Abrahams (1901, cited in Petran, 1932) found a positive correlation between AP and music creativity. It arouses an early interest in music (Gregersen & Kumar, 1996;

Without doubt, AP helps to recognize isolated tones (Boggs, 1907; Révész, 1953; Bachem, 1954; Ward, 1963; Paulson et al, 1967; Viscott, 1970; Slonimsky, 1988; Miller, 1989; Kreigen, 1997; Macpherson, 2000), intervals (Slonimsky, 1988; Miller, 1989; Levitin, 1998) and chords (Viscott, 1970; Slonimsky, 1988; Kreiger, 1997; Marvin & Brinkman, 2000). It guarantees a keen sense of pitch (Seashore, 1919, 1967; Corliss, 1973) and helps to detect pitch errors (Takeuchi & Hulse, 1993). It helps to comprehend melodies (Wallaschek, 1892, cited in Petran, 1932) and tell notes of the alto part (Eppstein, 1997). It helps to master tonal relationships (Seashore, 1967; Shuter-Dyson & Gabriel, 1981; Hantz et al, 1997; Siegel & Siegel, 1997), follow keys (Vernon, 1942a; Richard, 1942; Révész, 1953; Miller, 1989; Dowling, 1999; Marvin & Brinkman, 2000) and modulations (Stumpf, 1883, 1890, cited in Petran, 1932; Vernon, 1942a; Révész, 1953; Bachem, 1955) in extended music. It helps to produce tones too (Révész, 1953; Siegel, 1972; Rakowski, 1979; Rakowski & Morawska-Bungelar, 1987; Wynn, 1992).

AP helps ear-training (Burns, 1999). It facilitates music listening (Liebscher, 1908, cited in Petran, 1932). It helps subjects to memorize music (Bachem, 1955; Chang, 2003). Music heard can be memorized and played back instantly (Boggs, 1907; Minogue, 1923; Rife & Synder, 1931; Owens & Grimm, 1941; Scheerer et al, 1945; Anastasi & Levee, 1960; Viscott, 1970; Charness et al, 1988; Brown, 1999). AP helps to tune instruments (Brammer, 1951; Bachem, 1955; Miyazaki, 1993; Parncutt & Levitin, 1999; Chang, 2003) and play instruments in tune (Révész, 1953; Eaton & Siegel, 1976). AP possessors can be the pitch pipe for choirs (Chang, 2003).

AP helps one to sing in tune (Dickinson, 1999), sing unusual intervals (Révész, 1953), sight-sing (Révész, 1953; Eaton & Siegel, 1976, Miyazaki, 1995; Dowling, 1999; Burns, 1999), sing a-cappella (Révész, 1953), sing atonal music (Parncutt & Levitin, 1999) and hum tunes after hearing (Rife & Synder, 1931).
It helps to sight-read (Miyazaki, 1992, 1993; Chang, 2003) and know what music sounds like by reading scores (Eaton & Siegel, 1976). It helps to dictate (Miyazaki, 1992, 1993; Brown, 1999) and transcribe heard music into notations (Miyazaki, 1993, 1995; Krieger, 1997; Brown, 1999). It helps to analyze music, trace tonal structure (Miller, 1989; Parncutt & Levitin, 1999) and study atonal music by ear (Crutchfield, 1990).

AP helps to compose music (Chang, 2003). It enables composers to work originally with tones, not only with intervals (Abraham, 1901, cited in Petran, 1932). Most AP musicians can improvise music (Abraham, 1901, cited in Petran, 1932; Urbach, 1908, cited in Petran, 1932). About one-third of Abraham’s (1901, cited in Petran, 1932) AP subjects reported transposing being difficult and unpleasant, and the other two-third having no difficulty. Corliss (1973), as an AP possessor, confessed that he did not enjoy transposing because it sounded peculiar to him. But he had no difficulty in doing it. AP helps to transpose music because AP possessors know which notes sound right (Chang, 2003). Conductors can rehearse (Miyazaki, 1993) and conduct music in tune (Révész, 1953). They can lead a cappella choir in tune easily (Bachem, 1955; Ward, 1999).

AP facilitates a rich auditory imagination, such as tone colours (Bachem, 1955; Miller, 1989; Macpherson, 2000), brilliance and texture associations (Miller, 1989). It fulfils musical enjoyment (Stumpf, 1883, 1890, cited in Petran, 1932; Wallaschek, 1892, cited in Petran, 1932), a fuller pitch appreciation (Seashore, 1919; Slonimsky, 1988) and the pleasure from the perception of tonal relationships (Seashore, 1919) in long and complicated music.

Besides music, AP helps the perception of environmental sounds, such as train whistles (Auerbach, 1906, 1924, cited in Petran, 1932; Chang, 2003), dialing tones (Eppstein, 1997) and vehicle horns (Eppstein, 1997; Chang, 2003). One may tell the car speed from the pitch of running tires (Ward, 1999; Chang, 2003), from the pitch of the motor (Ward, 1999) and telephone numbers from dialing tones (Chang, 2003). Gregersen (1998) indicated that some AP persons possess exceptional mathematical and memory ability, and perceptual
acuity, such as taste and chromesthesia.

To musicians and researchers who favour AP, AP is “rather highly prized by musicians” (p.7), especially valuable for singers, violinists and composers (Petran, 1932). It is “an asset” (Eaton & Siegel, 1976, p.289) a “desirable ability” (Takeuchi & Hulse, 1993, p.345), as well as a “musical endowment” (Ward 1999, p.265) to musicians.

2.13.2. Cons

Some investigators have commented that AP may be a disadvantage rather than a help. AP possessors perform weakly in RP tasks (Burns & Ward, 1978; Miyazaki, 1992, 1993, 1995; Burns & Campbell, 1994; Parncutt and Levitin, 1999). They have difficulties in perceiving key relationships (Miyazaki, 1995) or learning a deviated scale (Cuddy, 1977). Pianists feel confused in playing pianos with different tunings (Planck, 1893, cited in Petran, 1932) or out of tune (Chang, 2003). Violinists may not play the violin in tune, but are distressed when playing out of tune (Krieger, 1997). They are uncomfortable to play works with accompanying pianos out of tune (Révész, 1953). Singers have difficulties in singing music in different keys (Sundberg, 1991), singing transposed music (Miyazaki, 1995; Parncutt & Levitin, 1999) or performing works with out of tuned accompanying pianos (Révész, 1953). They may still sing out of tune (Abrams, 2001).

AP exerts no helps in composition (Révész, 1953). Composers with AP, such as Mozart, Berlioz, Scriabin, Messiaen or Boulez, do not write better music than composers without AP, such as Berlioz, Wagner, Tchaikovsky, Ravel or Stravinsky (Parncutt & Levitin, 1999). AP musicians found it hard to transpose (Wallaschek, 1892, cited in Petran, 1932). AP does not help in aesthetics (Auerbach, 1906, cited in Petran, 1932; Révész, 1953) and music enjoyment (Révész, 1953). It disturbs listening when music is not in tune (Halpern, 1989; Miyazaki, 1995), transposed or of shifted tuning (Miyazaki, 1995). The awareness of pitch labels detracts listeners from enjoying music (Parncutt & Levitin, 1999).

Révész (1925) regarded AP the most important musicality among all. However, he did not view it as a musical talent. He argued that it was only a motive to develop musical talent.
In Weunent's (1929, cited in Petran, 1932) study, 20 (90.9%) out of 22 musicians found AP disturbing. Davis (1978) indicated that RP was generally accepted as a sense crucial to music performance, while AP was a sense of no musical advantages. Sundberg (1991) stated that “AP is often a nuisance” (p.52). It is not ‘a proof of an exceptionally high degree of musicality”. Miyazaki (1992, 1993, 1995) pointed out that some AP persons do not develop RP fully. They encounter all music situations in AP. AP becomes an ‘inability or a handicap’ (1993, p.70), considering RP being essential in music. Krieger (1997) argued that AP “does not guarantee musical success”, and it is “a disadvantage” (p.2 of 5). Dickinson (1999) explained that AP “doesn’t necessarily correlate with musical talent” (p.114). Dowling (1999) commented that “AP is not an essential ability for the understanding of most music” (p.613). It may be a hindrance to music cognition if the RP development is hindered by AP. Weinberger (1999) argued that AP is not required to achieve musical skills and AP musicians are not more accomplished than the non-AP. Even though the left planum temporale of AP musicians is larger than that of the non-AP (Schlaug et al, 1995), this is related to AP rather than to the musical talent. It was found that the auditory cortex corresponding to piano tones is larger in musicians than in non-musicians (Pantev et al, 1998). The greater the size, the younger is the age. AP is not a contributing factor either.

2.13.3. Codetta

It was generally accepted that AP helps in identifying elements concerning the pitch in the absolute sense. Other parameters are arbitrary. Even though AP possessors were judged to be weak in RP tasks, transposing, playing instruments, singing or listening to music with different tunings, out of tune or transposed, some AP musicians reported in the literature that they used AP to do these jobs well. They were Pepito Anesla (Richet, 1900, cited in Shuter-Dyson & Gabriel, 1981), Erwin Nyiregyhazy (Révész, 1925, 1953), a youngsters reported by Révész (1953), Louis Armstrong (Collier, 1983), Slonimsky (1988), Zach Glodberger (Rutz, 1996), Tony Kaye (Krieger, 1997), Wolfgang Amadeus Mozart (Willet,
2001; Hamer, 2001) and Roy Bogs (Hall, 2002). In addition to the excellent memory for tones, chords and music, they could transpose and improvise music well. Musical savants did these tasks well too. They are XY (Minogue, 1923), the savants with severe learning difficulties mentioned by Rife and Snyder (1931), L. (Owens & Grimm, 1941), L. (Scheerer et al, 1945), S. (Anastasi and Levee, 1960), Harriet (Viscott, 1970), J.L. (Charness et al, 1988), NP (Sloboda et al, 1985), the two autistic savants reported by Hermelin et al (1987), the autistic savants mentioned by Rimland and Fein (1988), QC (Mottron et al, 1999), Dominic (Heaton et al, 1999), the blind savants described by Rife and Snyder (1931), Judy (Burlingham, 1976), C. A. (Comer, 1985), the three blind savants mentioned by Hermelin et al (1987), the blind man examined by Hermelin et al (1989) and Thomas Wiggins (Miller, 1989). AP possessors may not have difficulties in doing RP tasks. It depends solely on training. Refer to Appendix III.2, pp.329-334 for the persons of exceptional music abilities with AP.

About one-third of Abraham’s (1901, cited in Petran, 1932) AP subjects reported transposition difficult and unpleasant and the other two-thirds reported having no difficulty. Corliss (1973), as an AP person, pointed out that he did not enjoy transposing because it sounded peculiar to him, but he had no difficulty in transposing. Miyazaki (1993) found that some AP persons managed AP and RP well, and some could not. Dan (1998) was an AP possessor. Even though he would be confused if a cappella singing and a piece of music was pitched lower, he would rather have it than not. It was nonsense that people with AP would concentrate on individual notes so much that this would hinder them listening to the music as a whole. Anyway, the value of AP is still open to question (Vernon, 1977). Its utility "for most musical situation is debateable" (Burns, 1999, p.237).

2.14. Unclear Phenomena

Even after a century, AP still remains as a scientific mystery (Seashore, 1940; Siegel, 1974; Brown, 1999; Stary, 2002). The first issue concerns the aetiology. Whether AP comes from nature or nurture (Neu, 1948; Sundberg, 1991; Ward, 1999)? Why does AP develop in
some people, not in others (Halpern, 1989; Heaton et al, 1998; Zatorre et al, 1998)? Why do so few people have AP (Ward, 1999; Brown et al, 2001)? Why is the occurrence so rare even in musicians (Siegel, 1974; Siegel & Siegel, 1977b; Ericsson & Faivre, 1988; Halpern, 1989; Levitin, 1994)? Why do some people possess it without much training and why do some people not have it even after strenuous effort (Mull, 1925; Ward, 1999)? It is the genesis of AP that has not been resolved (Miyazaki, 1989).

The second controversy is the criteria for deciding AP ability (Stanaway et al, 1970). The standard of an objective measure for AP has not been determined (Brady, 1970). Thirdly, its characteristics are rarely revealed (Ward, 1999; Macpherson, 2000; Brown et al, 2001), such as the brain processing mechanism (Siegel, 1974; Ward, 1999; Macpherson, 2000), the way labels anchored with tones (Siegel, 1974; Ward, 1999; Brown et al, 2001; Saffran & Griepentrog, 2001) and the influence of one’s aptitude for music (Shuter-Dyson & Gabriel, 1981). Fourthly, the value of AP is debatable (Vernon, 1977). Its utility in music is subject to testing (Burns, 1999).

2.15. Coda

In this chapter it was attempted to review all the aspects of AP in the literature. Unfortunately, most of the issues are still debatable, such as its definition, etiology, characteristics, processing, measurement, training methods and value. As Levitin and Zatorre (2003) stated, AP comes from “some yet unknown substrate … in interaction with right input at the right time” (p.109). Eighty years ago, Mull (1925) suggested a solution to the query of AP. The convincing proof comes from the “success in training average individuals in AP” (p.475). Seventy years later, Ward (1999) suggested a similar method. The nature of AP can only be resolved if “some technique for teaching AP is developed that would succeed with everyone, or at least with all children” (p.270). Otherwise, most features of AP can hardly be revealed truly.