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NON-VERBAL PARADIGM FOR ASSESSING INDIVIDUALS FOR ABSOLUTE PITCH

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Autistic individuals have been observed to demonstrate high intelligence through musical communication, leading to many empirical studies on this topic. Absolute Pitch (AP) has been a captivating phenomenon for researchers, although there has been disagreement regarding AP percentages among the population and appropriate testing methods for AP. This study analyzed data collected from 118 people, using a pitch matching paradigm designed specifically to be inclusive of those who are likely to have note-naming difficulty due to communication challenges. Thirty-eight participants were autistic individuals, 32% of which were considered to have severe language impairment. Twelve other participants had other developmental disorders. All but 1 of the 38 autistics (97%) demonstrated exceptional and instantaneous pitch matching abilities on piano. Ten of the 12 (83%) with other developmental disorders demonstrated this ability, and approximately half (53%) of neurotypicals were able to exhibit this ability. Our numbers indicate that with a more inclusive paradigm for assessing AP, it may be demonstratable in close to 50% of the population, and near 100% in the autistic population. This testing method represents a neurodiversity-friendly and fully inclusive, non-verbal paradigm for demonstrating AP.

KEYWORDS: Absolute Pitch, autism, music therapy, non-verbal, piano, relative pitch, savant.

INTRODUCTION

Numerous studies have suggested that autistic people may perform better than non-autistic controls across a variety of tests of perceptual processing, including visual search (Plaisted, O'Riordan, and Baron-Cohen 1998; O'Riordan et al. 2001), block design (Shah and Frith 1993), fine detail processing (Dakin and Frith 2005), and pitch discrimination (Heaton, Hermelin, and Pring 1998; Bonnel et al. 2003). A commonality among these paradigms is that the tests require pure processing of raw information, a literal interpretation of the external environment. The observation of the autistic advantage in these domains, in combination with perceived challenges

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in other domains, have led researchers to create different theories to explain the functional differences of the autistic brain relative to the more typical brain. One theory, known as "weak central coherence" theory, acknowledges that the autistic brain has superior local processing, but believes it engages poorly in holistic or global processing (Frith 1989; Frith and Happé 1994). Another theory, known as "enhanced perceptual processing" theory, also recognizes superior autistic local processing, but cites evidence that the autistic brain may not have deficits in holistic or contextual processing (Mottron and Burack 2001; Mottron et al. 2006). While the theories differ regarding autistic global processing, they both agree that autistic people tend to have superior elementary perceptual processing.

Anatomically, there are differences between the autistic and more typically developed brain that provide evidence that speaks to the observed functional differences. For example, it has been observed that in early childhood, the autistic brain tends to have more total grey matter than other brains (Courschesne, Redcay, and Kennedy 2004; Courchesne et al. 2005). As the brain develops, there is a tendency toward enhanced local circuitry at the expense of a decreased number of long-range connections (Courchesne et al. 2005, 2007). The result is what could reasonably be expected from such a pattern of neural circuitry: enhanced processing of basic perceptual information, but an attenuated ability to integrate perceptual information and form general associations.

Communication disorders are inherent in the DSM-5 diagnostic criteria for autism spectrum disorders, thus, any experimental paradigm that includes a language component will inherently be biased against the autistic population (Dawson et al. 2007; Soulieres et al. 2011). For the reasons described above, this means that an experimental design intended to test something irrelevant to language but including a language component will be automatically more challenging for autistic subjects. Autistic subjects may struggle completing the task, without struggling with the actual task manipulation itself. This is a major problem, because it can lead to misinterpretation of results and misrepresentation of the true skill set of the autistic participants in the study (Dawson et al. 2007; Soulieres et al. 2011; Barbeau et al. 2013).

Absolute Pitch (AP) traditionally has been tested by having subjects provide a verbal or written response indicating the letter of the alphabet associated with the musical tone that had just been heard by the subject (Bachem 1937). This is a classic example of a paradigm incorporating language components (associating a tone with a letter, associative reporting of that letter), which are irrelevant to the actual task manipulation itself (does the subject know the precise tone that has just been heard?). Thus, this task is inherently biased against autistic subjects, or anyone else with language-related differences, and the results will not represent an accurate reflection of the true skill set of these subjects regarding AP. Stereotypes and myths about AP arise from paradigmatic assumptions of our current culture which are "the deepest of beliefs in how systems work" (Meadows 2008, p. 163). Cross-cultural barriers in assessing for AP can be imagined in tribal cultures without a written language, and where ceremonial chants are sung in the same key time after time, without any reference to pitched instrument. After all, "communication" is not something one "says," but rather an elaborate, embodied experience and cultural ritual of what one is observed to do.

To accurately test for AP in language-impaired individuals, a paradigm that does not include a language component must be used (Heaton, Hermelin, and Pring 1998; Mottron, Peretz, and Menard 2000). A paradigm is a "mindset out of which the system—it's goals, structure, rules, delays, parameters—arises" (Meadows 2008, p. 162). This paradigm shift should involve a newer definition based on an assessment where a language component is not considered. The term "paradigm" further captures the notion that AP has historically been tested by strict note-naming, at the exclusion of the verbally impaired, and that our approach represents a paradigm shift away from this somewhat antiquated, exclusive method. Further, the notion that such high percentages of the general population can exhibit this ability, also represents a paradigm shift away from what has traditionally been considered a rather unique, exclusive skill. Rather than an approach or method for assessment, we hope to establish a new paradigm for how AP may be considered, both for the verbally impaired and for the general population.

Here, we propose that a non-verbal paradigm using pitch-matching, whereby subjects are required to play on a piano the precise tone just heard, captures the manipulation critical to AP (does the subject know the precise tone) without contamination from irrelevant language components. This testing method relied on research indicating that autistic individuals have a raw ability to match pitches without substantial musical training.

Previous literature indicates that population percentage estimates exhibiting AP depend on the method used for testing AP (for review, see Takeuchi and Hulse 1993). For example, estimates as low as 1 in 10,000 have been obtained using methods of presenting rapid, successive sine-wave tones requiring verbal responses (Profita and Bidder 1988). Furthermore, what is considered "Absolute Pitch" varies in the literature. Traditionally, definitions of AP have required that subjects are able to name any note, including flats and sharps, across a range of octaves. However, more inclusive definitions of AP acknowledge that some people exhibit AP skill only for pure tones (excluding sharps and flats) and/or only over limited octave ranges (Bachem 1937). Such abilities are still considered on the AP spectrum proposed by Bachem (1937), rather than the Relative Pitch (RP) spectrum, as long as subjects' reporting of tones is done immediately and without opportunity to use a reference tone to orient themselves. Indeed, while there are many diverse definitions of "perfect pitch" and "absolute pitch," the one common thread is that they are distinct from "relative pitch" in that no reference tone is necessary for the possessor to execute the task for the assessment paradigm being utilized.

Absolute Pitch Dissolves during Typical Development

While possessors of AP generally are considered rare in the adult human population, several lines of evidence speak to the notion that AP is actually an automatic process that much of the population is born with, and that as infants reach certain developmental milestones, there is a shift from use of AP to RP cues (Snyder and

Barlow 1988; Saffran and Griepentrog 2001; Saffran 2003). Evidence leads us to believe that this shift may be an evolutionary trait necessary for the acquisition of language, as inhibiting the awareness of raw details of frequency components such as pitch, yields to the meaning of sounds as suggested by Snyder and Mitchell (1999).

Researchers have postulated that in some cases, this shift from AP to RP processing does not occur, and the absence of this shift may be related to the possession of AP. Loss of AP is thought to be part of a process by which typically developing people shift from processing the world in literal terms to processing the world in more task-relevant terms (Snyder and Mitchell 1999). The idea behind this is that initially our perceptual processing systems read out the physical environment in a raw fashion, but then, over the course of many iterations of interactions with the world, it "learns" that holding on to all the raw details of an image or sound is not the most efficient means by which to operate (Snyder and Barlow 1986). Thus, while there may still be some processing of functionally irrelevant details, they are generally suppressed from consciousness because it would be overly burdensome and counterproductive to be aware of them (Snyder, Bossomaier, and Mitchell 2004).

Absolute Pitch and Autism

There have been numerous phenomenological reports of exceptional musicality in the autistic population, and researchers have sought to find a neurological connection to this phenomenon. In prodigious individuals such as savants, matching on piano and evidence of AP occurs in early childhood (Treffert 2006). Thus, the automated response to pitch matching on the piano may be a primal ability that AP possessors can achieve even if they miss further milestones at two years of age and beyond. In fact, most savants possess AP, even if they are of the calender-calculator savant categorization (Treffert 1989).

There are lines of evidence suggesting that the shift from processing in raw, absolute terms to processing in more functionally relevant terms is something that does not fully occur in autistic populations. In the area of musical talent, Heaton, Hermelin, and Pring (1998) have shown that musically naive autistic children are significantly better than matched controls at learning labels (note names) for individual pitches—the ability underlying AP (Heaton, Hermelin, and Pring 1998). The possession of AP itself is widely regarded as a savant-like property, and numerous investigations have indicated that non-autistic people who possess AP typically score higher on autistic measures than controls do (Brown et al. 2003; Dohn et al. 2012). Thus, the very nature of having AP is something that can be considered somewhat "autistic." It has also been hypothesized that there is a "cost" for those who possess it (Zatorre 2003), as cited by Bossomaier and Snyder (2004).

The challenge of creating a paradigm to test AP in pre-verbal, non-verbal, and non-musically trained individuals is one that has been addressed by various methods. Autistic subjects have previously been assessed using tone to animal picture matching (Heaton, Hermelin, and Pring 1998), and tone to staircase graphic

(Heaton et al. 2008), and identifying whether melodies were played in a transposed key or not (Mottron, Peretz, and Menard 2000). Testing by these methods requires enough training and reliance on advanced cognitive processes so that the participants are able to develop an association between a particular note and a particular item of interest.

Brain Circuitry Involved in Pitch Perception

Any judgment about any stimulus processed via any sensory modality occurs by the same general mechanism: somehow, the brain must read out the activity within the perceptual system processing the information, and make a determination about the physical properties of the stimulus based on the pattern of activity elicited. We know something has touched our hand because hand-specific neurons in somatosensory cortex become activated. We know something is in a particular location of a visual field because specific areas of visual cortex serving that location are activated. Likewise, we know the specific tonal frequency of an auditory stimulus by the pattern of activity of specific neurons in auditory cortex.

The auditory system is organized tonotopically, meaning that where a sound is encoded in an auditory processing structure is determined by its pitch (i.e., its tonal frequency). This is true from the cochlea through the auditory cortex (Carlson 2013). Thus, the determination of pitch is, in fact, the most raw or fundamental readout of auditory information. Most humans are quite good at making pitch discriminations in the context of whether a particular tone was higher or lower (frequency) than one just previously heard, and can generally make such distinctions with tonal frequency differences as small as 0.8% (Tervaniemi et al. 2004). Thus, at some level, humans are rather good at reading out the activity in their auditory cortices to make judgments about the tonal information processed there. What is unique about what is generally considered AP is that it requires a working representation of which frequencies correspond to which musical notes. Then, when the person hears a particular frequency, the judgment becomes one of matching the tonal frequency to the working representation of the frequency–note association.

A very low percentage of the population exhibits AP in this capacity. Although it is difficult to determine whether this is due to an inability to create the frequency–note association or an inability to match the heard frequency to this representation, based on the tonal discrimination ability of most individuals, it seems more probably a deficiency in the former than the latter. In autistic individuals, sensory integration differences account for the overarching perceptions in one area of processing without integrating to other areas as observed in neurotypical brains. Therefore, sound may accumulate, and be processed with great intensity, and even overload the listener for its high levels of detail. In a study using transcranial magnetic stimulation (TMS) to induce inhibition, savant abilities in art and editing emerged for about fifteen minutes (Bossomaier and Snyder 2004). With TMS, AP can possibly be induced in subjects through temporary TMS-induced inhibition per the agent-based computational model proposed by Bossomaier and Snyder (2004).

The development of a frequency–note association representation is a complex abstract process that is often thought to occur more through automatic mechanisms than through conscious effort (Baird 1917; Deutsch 2002). It is more likely an example of implicit than explicit learning. The aspect of ascribing a letter (plus sharp/flat descriptors) to be associated with the frequency adds a level of abstractness to the process beyond just a working representation of frequencies. This is especially true for a typical American person tuned to a C major diatonic scale, which has no sharps or flats. As explained earlier, these processes of associating the frequency with a verbal descriptor and later having to articulate the descriptor are tasks that are inherently biased against communication-challenged individuals.

Redefining the Paradigm

Whether one can actually form and retrieve the frequency–note association is critical to the classic note-naming definition of AP, but the absence of this association does not necessarily preclude one from possessing AP in the pure sense. A working representation of frequencies can still be stored in individuals, such that they can match the tone being heard to this representation, just as someone possessing the frequency–note association would. The challenge then becomes how to test such individuals such that they can exhibit their ability to match a tone to their working frequency representation.

While other methods have been developed attempting to accomplish this (Heaton 2003; Heaton et al. 2008), we believe the keyboard pitch matching paradigm accomplishes this in a more musically relevant and organic fashion. For many individuals with AP, a consistent ability to sing a familiar song from memory in the exact key as the album recording without a reference, has long been overlooked and underused as an assessment variable (Rancer 2005). Individuals who were able to sing a familiar song in the exact key as its album recording, all tested positive for AP in this study. In order for one to be able to pitch match using the piano, the person must be able to match the pitch to the stored representation and recognize what piano key this corresponds to.

METHODS

Participants

This study analyzes data from 118 individuals (55 females, age range 5–67) who had been assessed for AP, with a non-verbal paradigm using piano pitch-matching (Rancer 2005). The 118 participants (38 Autism Spectrum Disorder [ASD], 12 Other Developmental Disorder [OD], 68 neurotypical subjects [NT]) had varying levels of musical expertise, but all participants had been determined to have sufficient musical background to be familiar with a piano keyboard. Of the 38 Autistic subjects, all had participated in music therapy and been introduced to “Keyboard Talent Hunt: Book One” by Schaum Publications, for at least six sessions on piano prior to testing. All 12 of the OD group had also participated in music therapy and consisted of primary diagnoses of 3 Dyslexia, 3 Attention Deficit Hyperactivity Disorder (ADHD), 2 Down’s syndrome, 1 Temporal lobe epilepsy, 1 Pierre Robin syndrome, 1 Mobius syndrome, and 1 Schizophrenia. The 68 NT had received varying degrees of musical training, as explained below. The music therapy sessions were not geared toward developing AP, and no trials of the task had been attempted by any participants prior to testing.

Autistic (ASD) and "other diagnosis" (OD) participants consisted of the entire client-base of a music therapy private practice in California. The neurotypical participant pool was a combination of active musicians in New York and music conference participants in Boston, MA. Thus, the data available for this study did not include perfectly age-matched "controls" in the conventional sense. All subjects who were invited to take the test agreed to do so; there was therefore no self-selection of subjects from within any setting. The test was administered to the two groups under similar parameters, but somewhat different conditions. In the music therapy practice, all clients were assessed when they came for their scheduled sessions. The room was sometimes noisy, and resounding with siblings' and/or parent's conversation. The tasks were explained to subjects, and their parents gave permission to proceed with the assessment. In New York and Boston, participants were recruited verbally, permission was obtained, and tasks were explained to subjects. The assessments took place in an isolated and quiet piano practice room. In all cases, participants were not compensated for their participation and had no prior preparation or knowledge of the nature of the research. Participants were debriefed following their assessment.

Procedure

Data were obtained from a series of assessments performed by a professional music therapist. The procedure used to collect the data was as follows: Participants were seated in front of one piano, hands placed in C major position. The tester was at a second piano alongside. The pianos were spaced about three feet apart. The tester held a large book in her left hand to cover her right hand, obscuring it from the subject's view. The tester then played a random note on the piano with her right hand. The subject was directed with a simple question, "can you find that for me on the piano?" All subjects were unaware that they would be tested at that moment. The response time of the initial pitch match was the most critical determination, for given a sufficient time lag, accuracy could be due to the possession of RP.

If the first pitch was matched within a couple of seconds, the next random pitch was played. After 10–15 pitches on average, a determination was made on the basis of accuracy (ability to pitch match $>80\%$ of tones played) and instantaneity. The assessments typically lasted about two minutes from start to finish. It was necessary to keep these assessments short due to challenges maintaining the interest and attention of participants. Assessments were extended when possible, and when extended, always maintained consistency with the first set of notes played. At least four individuals were tested for chord disentangling skills, but only to record their level of prodigiousness. Additional testing was completed for other tasks including improvisation and transposition, but will not be presented in this article.

Benguerel and Westdal (1991) proved that AP possessors do not identify pitch by interval relationship (as RP possessors do) but rather by absolute matching. Therefore, absolute matching on the first try for the first pitch played (which was never C4) was required. This reliance on first-time perfect accuracy on piano tones is even more stringent than the previously determined accuracy within a semitone (Baggaley 1974; Miyazaki 1988). The determination for AP to include pitch-matching as legitimate marker for the presence of AP for all ages, level of training, or diagnosis has been discussed previously in the literature (Treffert 1989; 2006).

RP was determined if the response time to the notes was very slow, and/or if the subject was only able to match a tone within the context of other tones. Some RP subjects responded fairly quickly, but spent time evaluating, or vocalizing to orient themselves to the correct pitch. If a subject failed to match the first note on the first try, then we continued to assess for RP. The tester played the middle C, and then asked the subject, "if this is a 'C', then what is this note? Play it." The tester then played a second note higher up in the same octave. The assessment continued by playing the middle C as the root reference, with different second-notes each time. Since RP is typically accomplished via interval determination (Benguerel and Westdahl 1991), the task was designed to provide subjects simple intervals from middle C to allow them maximal opportunity to demonstrate RP. If subjects were able to match the notes in this manner, they were categorized as having RP.

Data Analysis

It was determined that 30% of one's lifetime qualifies as musical training sufficient for the acquisition of NASM fundamental keyboard competencies (NASM 2013), and this 30% cutoff was the determination for whether or not participants were considered to have received "substantial musical training" (>30% of lifetime musically trained). The % of lifetime musically trained was calculated by dividing the number of years of musical training by the age of the participant. For each group, we calculated the percentage of participants who had received >30% lifetime training. Also, for each group of participants (Autistic, NT, OD), the group average % of lifetime musically trained was calculated by summing together the % lifetime training of each individual within the group, and dividing this by the number of participants in the group.

For all comparisons of interest, chi-squared tests were performed to check for significant between-group differences.

RESULTS

In total, 38 autistic individuals (Autistic), 68 typically developed controls (NT), and 12 participants with other developmental disorders (OD) were tested. Of them, 39% of autistic, 49% of NT, and 50% of OD participants had substantial (>30% of life) musical training (Figure 1). The remainder of participants had sufficient musical background to be familiar with a piano keyboard. Of the autistics tested, all except one (97%) were able to demonstrate AP. Of the neurotypical controls,

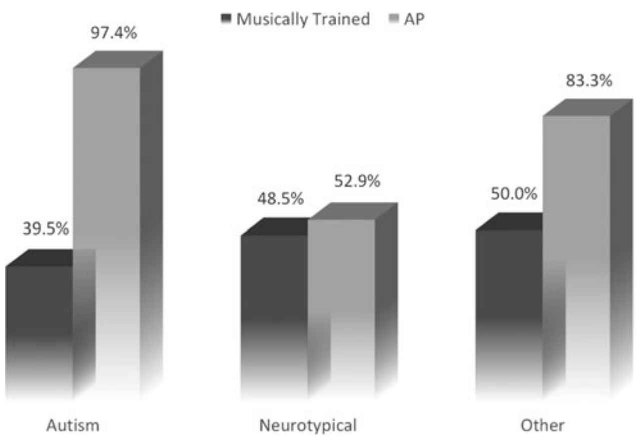

Figure 1. Absolute Pitch and Musical Training by group. Left bars of each cluster indicate the percentage of subjects from each group who received substantial musical training, as defined by >30% of one's lifetime. Right bars of each cluster indicate the percentage of subjects in each group who demonstrated Absolute Pitch in our pitch-matching paradigm.

37 (53%) were able to demonstrate AP, 29 (44%) were able to demonstrate RP, and 2 (3%) were unable to demonstrate either AP or RP. Of the other developmental disorder group, 10 (83%) were able to demonstrate AP, and 2 (17%) demonstrated RP (Figure 2). Chi-squared analysis revealed a significant difference between

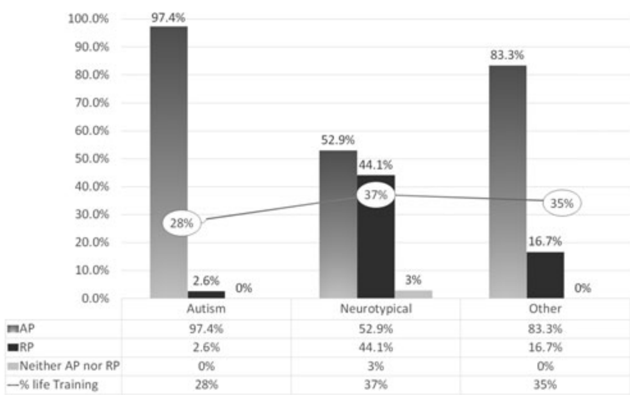

Figure 2. Absolute Pitch (AP), Relative Pitch (RP), and Average Musical Training by group. Leftmost bars of each cluster indicate the percentage of subjects in each group who demonstrated AP. Center bars of each cluster indicate the percentage of subjects in each group who demonstrated RP. Rightmost bars of each cluster indicate the percentage of subjects in each group who demonstrated neither AP nor RP. Oval labels on intersecting line indicate the average amount of lifetime musical training for each subject in each group.

autistic AP possessors and neurotypical AP possessors (X2 $\sim$ 21.34; $p < .001$; Odds Ratio (OR) $\sim$ 31.86). Group average % of lifetime musical training indicated that, on average, autistics had received training over 28% of lifetime, NTs received training over 37% of lifetime, and ODs received training over 35% of lifetime (Figure 2).

Findings were interpreted within the context of the AP spectrum as defined by Deutsch (2002; 2006) and Treffert (2009). Since some AP possessors can identify pitches but cannot produce pitches absolutely, there may be a regular hierarchy of AP in which effects of timbre, pitch register, and pitch class are apparent only at low levels and AP production ability is characteristic of high levels of AP. Subjects without instantaneous response were determined to have RP, a "functional time lapse" established by Bachem (1937).

DISCUSSION

The results of this piano pitch-matching study illustrate that high incidences of AP can be observed when people are able to demonstrate this ability in an organic, musical fashion. This is particularly so within the autistic population, where 37/38 (97%) were able to demonstrate AP by this method. Consistent with previous studies on AP, autistics exhibited a superior innate ability to demonstrate AP relative to controls (97% vs. 53%; X2 $\sim$ 21.79, $p < .001$; OR $\sim$ 31.86; Figure 2). This was true despite a lower average percentage of lifetime spent on musical training in the autistic group than in the NT group (28% vs. 37% on average, Figure 2).

As reported in the literature, AP performance tends to be heavily bimodal, with possessors scoring very high on AP tests, and non-possessors scoring very low (Lockhead and Byrd 1981; Miyazaki 1988). Persons without AP have been observed to ponder over the scale for a considerable time (up to 30 seconds), considering notes over a wide range, and then undecidedly pointed to a key which, off by as much as 20 half-tones (Bachem 1937). The response of AP possessors in other studies has been shown to be effortless and immediate (Bachem 1940; Corliss 1973; Profita and Bidder 1988; Révész 1953); possessors made no special effort to develop AP (Baird 1917; Boggs 1907; Weinert 1929). The observations made during the data collection process reflect this bimodal nature; participants either exhibited very high speed/accuracy or low speed/accuracy on the AP task.

Although piano may not be a typical part of today's stringent AP testing methodologies, it certainly played a role in much of the older AP literature. Bachem believed that the piano produces the most easily recognizable tones in which to identify pitch (1937), and he continued to test using piano for decades (Bachem 1955). In experiments by Carroll (1975) and by Lockhead and Byrd (1981), participants matched the pitch by playing back the corresponding note on a piano; however, sine tones were played rather than piano. AP discrimination tests in research should include non note-naming tasks in the search for possessors with communication differences and/or without a lifelong musical training background.

Some researchers claim that piano-played pitches provide identification clues through timbral cues (Lockhead 1982; Ward and Burns 1982), thus Zatorre's paradigm for assessing for AP involves pure sine tones played in random sequence at rapid pace from a recording. In recent years, Zatorre's published method has become consistently cited as the most absolute method to prove AP, which disregards the portion of the population that does not have the specific ability to note-name through vocalization. Furthermore, in being tested via sine tones, AP possessors must be able to demonstrate their ability in a highly artificial, inorganic setting. Many participants, especially autistic individuals, first need to form a trusting relationship throughout a period of time to best produce results at the time of testing. The collection of the data in this study required extensive therapeutic relationships between the testers and the participants, and would not have been possible with the technological incorporation of recorded sine tones, which can cause painful auditory response in many of the autistic subjects. Particularly in the young autistic children, tolerating headphones with recorded random tones was reported as especially challenging in the first few that were tested using this method. Finally, Bachem asserted that tests should be designed by AP possessors rather than psychologists who are not possessors (Bachem 1937). In this study, the entire research team was composed of individuals with the faculty of genuine AP and/or autism.

In our early exposure to sound, sine tones are non-environmental sounds for which we are not accustomed to identifying. Incorporating those timbres that are not perceived as acoustic quality typical sound would further exclude individuals who have grown to navigate typical sounds in their environment, such as the instrument that they play. Piano timbre was a necessity in this study, to ensure the multidimensional characteristic spectrum (waveform) of sound perception against tone identification (Grey 1977; Handel 1989). In considering pitch identification tasks, synthetic sine tones without timbral cues will not necessarily stimulate areas of the brain needed for processing the salient dimension of pitch in sound. This is because as concepts form in later developmental milestones, perception becomes increasingly selective for information relevant to the concept (Snyder and Mitchell 1999), and sine tones hold little conceptual value compared to sounds from musical instruments.

It is important to note that this assessment method determines the subject to meet the criteria of the AP spectrum defined by Deutsch (2002; 2006) and Treffert (2009). This is not to be confused with Musical Echolalia, as defined by Demaine (2012). Several subjects have been asked to compose, improvise, or transpose, to assess for Treffert's splinter skills defined as talented or prodigious (Treffert 2009). The creativity and intellect required to demonstrate such abilities is far greater than that required for echolalia, an imitation or shadowing of vocalization without intent. Our results and observations indicate the musical talent to be a result of the AP, and not the musical training. AP possessors without significant musical training demonstrated a high degree of talent. Savant musical abilities have been observed in these participants when enriched by a music therapy clinical setting.

For decades, it has been recognized that AP may be demonstrated to varying degrees or under particular circumstances. Bachem wondered in 1937 if "various grades and even different types of absolute pitch may occur" (p. 146). Even though AP is often thought of as something that people either possess or do not (i.e., bimodal results), people's abilities to demonstrate AP may be affected by the nature of the test administered. The most prodigious of possessors might be able to note-name sine tones, including sharps and flats, over a range of many octaves. Anecdotally, some are even able to name frequencies (e.g., "367 Hz"). But those able to pitch-match on piano without a reference tone are clearly demonstrating something other than RP, namely AP. The nature of the pitch-match allows a much higher proportion of the population to demonstrate AP ability than what is typically reported in the literature.

AP processing is the initial default mechanism for processing auditory information (Snyder and Mitchell 1999; Saffran and Griepentrog 2001). Furthermore, AP is thought to be something that still resides, but is generally inaccessible in most neurotypical individuals (Snyder et al. 2004; Bossomaier and Snyder 2004). Thus, it could be argued that the low incidence of AP previously reported is due to an inability of the testing techniques to tap into the neural circuitry required for most individuals to be able to exhibit AP. Inherent in note-naming tasks is the activation of language and communication circuitry, which may serve to counteract the primal absolute processing mode required to demonstrate the very skill being tested. We believe our pitch-matching paradigm taps into the more primal mode of processing by allowing for simple, instantaneous responses which circumvent conscious communication circuitry. Particularly for people who struggle with communication, pitch-matching on piano is an ideal assessment tool because it usurps the very laborious process of conscious communication for these individuals.

CONCLUSION

Pitch-matching on an instrument is a primal ability in untrained individuals with specific cerebral differences. This study was designed to establish the paradigm for testing individuals for AP in about two minutes, without note-naming, to include non-verbal individuals. This testing method can further be used to assess a greater variety of subjects previously excluded from AP studies, bringing a wider range of neurodiversity into future research. In investigating a paradigm that allows people to demonstrate AP without the highly specialized note–name association, we learned that many more people have the capacity to test positive for AP than the often quoted belief of 1 in 10,000 (Bachem 1955; Profita and Bidder 1988). Our numbers indicate that with a sufficiently exclusive paradigm and elementary musical familiarity, some form of AP may be demonstratable in 50% of the population, and near 100% in the autistic population.

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