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Aprosodia and prosoplegia with right frontal neurodegeneration

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ABSTRACT

Affective prosody and facial expression are essential components of human communication. Aprosodic syndromes are associated with focal right cerebral lesions that impair the affective-prosodic aspects of language, but are rarely identified because affective prosody is not routinely assessed by clinicians. Inability to produce emotional faces (affective prosoplegia) is a related and important aspect of affective communication has overlapping neuroanatomic substrates with affective prosody. We describe a patient with progressive aprosodia and prosoplegia who had right greater than left perisylvian and temporal atrophy with an anterior predominance. We discuss the importance of assessing affective prosody and facial expression to arrive at an accurate clinical diagnosis.

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Introduction

Human communication involves both what a person says and how that person says it. The same words can have very different implications if uttered with sincerity versus sarcasm, or with a smile versus a grimace. Research over the last 150 years has established that various aspects of propositional language may be disrupted by focal lesions of the left hemisphere, giving rise to aphasic syndromes. In contrast, focal lesions of the right hemisphere do not cause aphasic syndromes, but do cause deficits in the affective aspects of language and communication, including facial expressions.

Prosody is a paralinguistic aspect of language that is realized acoustically through variations in pitch, loudness, syllable and word duration, pauses, stress, tempo, and timbre. There are two major subcategories of prosody, linguistic and affective, each having a different neuroanatomical substrate (Ross, Shayya, & Rousseau, 2013). Linguistic prosody often clarifies the literal aspects of speech. Linguistic stress may emphasize part of a phrase or word to convey the correct semantic intent; for example, compare the semantic difference between “**hot-dog**” versus “hot **dog**,” or “**object**” (noun) versus “**object**” (verb). In contrast, prosodic stress and pausing may be used to clarify potentially ambiguous syntax and emphasize the most important word in a sentence (pragmatic intent). For

example, compare the following sentences with the exact same word order, “John e-mailed ... his **friend** from Denver” versus “John e-mailed his friend ... from **Denver**.” Affective prosody, on the other hand, layers emotional and/or attitudinal meaning on top of linguistic information (Ross & Monnot, 2008; Ross et al., 2013), which may alter communicative intent. For example, if the sentence “He is smart” is strongly stressed on “is”, it acknowledges the person's ability. A strong stress on “smart” with a terminal rise in intonation, however, indicates sarcasm. In addition, affective prosody can convey emotions such as anger, happiness, fear, or surprise. In non-tone languages, such as English, the manipulation of pitch over time (intonation) appears to be the most salient acoustic correlate of affective prosody (Ross, Edmondson, & Seibert, 1986).

The neuroanatomic substrate of prosody is complex. Affective prosody is disrupted by focal lesions of the right hemisphere that give rise to various clinical syndromes, called aprosodias, which are analogous to the aphasic syndromes observed after focal left hemisphere damage (Ross, 1981). The Aprosodia Battery (ApBat; Ross & Monnot, 2008; Ross, Thompson, & Yenkosky, 1997) was developed specifically to detect patterns of deficits in affective prosody associated with left versus right brain damage under incrementally reduced verbal-articulatory demands. In patients with left brain

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damage, reducing the verbal-articulatory demands results in near-normal improvement for both affective-prosodic repetition and comprehension. In contrast, in right brain damage reducing verbal-articulatory demands does not result in improvement for either affective-prosodic repetition and comprehension. The neurology of linguistic prosody is more complex than affective prosody. The most studied aspect of linguistic prosody is production of prosodic stress in patients with focal brain lesions (Ross et al., 2013). Both left and right brain lesions disrupt prosodic stress equally. However, disruption of prosodic stress is not closely related to lesion location within the right hemisphere or the presence of aprosodias. In contrast, disruption of prosodic stress is highly correlated with aphasic non-fluency and lesions injuring the basal ganglia in the left hemisphere.

Neurodegeneration involving the left frontal operculum causes the non-fluent variant of primary progressive aphasia (nfvPPA; Gorno-Tempini et al., 2011; Pressman & Gorno-Tempini, 2015), characterized by progressive motor speech deficits that have been labeled “apraxia of speech.” Apraxia of speech is characterized by several speech errors, including what has been commonly described as a “loss of prosody”. This loss of prosody, however, has not been specified as being linguistic or affective. Furthermore, almost all of the acoustic studies involving “loss of prosody” associated with nfvPPA (Ballard et al., 2014; Duffy et al., 2017) have measured pauses and speech rate but not pitch variation, thus assessing linguistic rather than affective prosody.

Focal lesions that acutely damage the right frontal operculum are associated with the syndrome of motor aprosodia (loss of spontaneous affective prosody and affective-prosodic repetition with preserved comprehension of affective prosody; Ross & Monnot, 2008). In addition, right hemispheric damage, including in patients with neurodegenerative disease, has been associated with impaired ability to intentionally make or imitate facial expressions of emotion (“affective prosoplegia”; Ghacibeh & Heilman, 2003; Gola et al., 2017) that overlaps with the syndrome of motor aprosodia. In contrast, buccofacial apraxia tends to lateralize to the left hemisphere (Kwon, Lee, Oh, & Koh, 2013) and often overlaps with speech apraxia (Botha et al., 2014; Graff-Radford et al., 2014).

In this case report, we describe a strongly right-handed patient who presented with progressive language deficits characterized as a moderate apraxia of speech with “loss of prosody” consistent with the diagnosis of nfvPPA (Gorno-Tempini et al., 2011). On imaging, he was expected to have predominantly left fronto-opercular and anterior-superior atrophy. Instead, his imaging showed predominantly right frontal atrophy. We initially thought this patient may represent a case of “crossed aphasia” (Spinelli et al., 2015). However, further history from his wife suggested that his initial deficits involved emotional expression, and formal assessment demonstrated severe deficits involving spontaneous affective prosody and affective-prosodic repetition with relative sparing of affective prosodic comprehension. He was also unable to intentionally produce facial expressions. Thus, these findings are consistent with his predominantly right-sided atrophy.

Case history

AP is a 58-year-old right-handed man with 18 years of education who was evaluated at the University of Colorado Neurobehavior Clinic for progressive impairment of speech. Although his wife reported that he had had a life-long tendency to avoid emotional displays, she stated that over the previous several years he had become more emotionally flat in his verbal expression. Because of his increasing emotional flatness, she had wondered whether he was depressed. Approximately 1 year before his evaluation, he developed deficits in speech articulation, especially when pronouncing multi-syllabic words. This problem led to an evaluation of bulbar-onset motor neuron disease. However, electrodiagnostic studies were normal. The patient reported no difficulties with memory, attention, visuospatial processes, or manual praxis. He continued to work in a high-level technical position and had not received any complaints about his performance at work. His written communication remained excellent. Both the patient and his wife denied mood disturbances or personality changes other than flattening of emotional expression.

On neurologic examination, the patient had stereotypic random rapid tightening of the corners of his lips, and mild paratonia in the distal extremities. His posture was somewhat stooped and there was mild hypomimia. His overall Unified Parkinson’s Disease Rating Scale (Fahn, Elton, & Committee, 1987) score was 14. The remainder of his neurological examination was normal. On neurobehavioral testing, AP’s language was characterized as nonfluent with impaired confrontation naming, and impaired verbal agility in the context of intact single-word comprehension and relatively preserved syntactic comprehension. His performance on a brief sentence repetition task was also impaired, primarily because of distorted sounds consistent with apraxia of speech. His score on the Montreal Cognitive Assessment (Nasreddine et al., 2005) was 24. A brain MRI demonstrated predominant right frontal atrophy (discussed below). Routine blood tests for reversible dementia were unremarkable.

To further analyze the neurobehavioral deficits specific to AP, a comparison case was identified who had nfvPPA and left greater than right fronto-insular atrophy. This individual is a 68-year-old right-handed man with a Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) score of 26, and 24 years of education. On the Western Aphasia Battery (WAB; Kertesz, 2007), his fluency score was 5 and his information content score was 9. He was diagnosed with pronounced apraxia of speech, featuring slow and halting articulation, and several revisions of phrases (perhaps to help with initiation), and many instances of poor initiation and groping. His speech was sometimes unintelligible, and both speech and writing were agrammatic.

Neuropsychological evaluation

Neuropsychological testing was completed in both patients (Table 1). AP had impaired abstract thinking, simple attention, and verbally mediated processing speed, with lesser (but still mild) impairment in visually mediated processing speed. All measures of fluency (including nonverbal measures) were at

Table 1. Neuropsychological results.

Patient ID	AP	nfvPPA
Memory		
California Verbal Learning Task – Short Form		
Learning trial 1 (9)	5 (–2.1)	3 (–4.1)
Learning trial 2 (9)	7 (–0.2)	6 (–1.2)
Learning trial 3 (9)	6 (–4.0)	7 (–2.3)
Learning trial 4 (9)	7 (–3.2)	8 (–1.2)
30-second recall (9)	7 (–1.5)	8 (–0.3)
10-minute recall (9)	7 (–0.6)	7 (–0.6)
Recognition (9)	9 (0.5)	9 (0.5)
Benson recall (17)	8 (–1.7)	11 (–0.5)
Benson recognition (Y/N)	Correct	NA
Visuospatial		
Benson copy (17)	15 (–0.5)	14 (–1.5)
Calculations (5)	5 (0.3)	3 (–2.6)
Attention, Speed, and Executive Function		
Digit span forward	4 (–2.7)	3 (–3.5)
Digit span backward	3 (–1.8)	2 (–2.6)
FAS fluency	12 (–2.9)	1 (–3.9)
Category (animals) fluency	16 (–1.1)	4 (–3.1)

FAS = letters F, A, and S; NA = not available. z-Scores in parentheses calculated from normative data from the University of California San Francisco Memory and Aging Center (Kramer et al., 2003).

least mildly impaired, and he had mild retrieval deficits in visual memory. Verbal memory and visuospatial functions were normal. He also scored well on a face perception task (12/12) and on a task involving the naming of affective facial expressions (13/16). The patient with nfvPPA performed similarly on all tasks of abstract thinking and simple attention, though he performed markedly worse on tasks of lexical and semantic fluency.

Language evaluation

Speech and language evaluation was completed on both patients, and included a modified WAB (Kertesz, 2007), a short-form of the Boston Naming Task (Mack, Freed, Williams, & Henderson, 1992), a syntax comprehension task (Wilson et al., 2010), and a thorough motor speech evaluation (Table 2).

Verbal output was recorded and evaluated independently by two speech-language pathologists (HIH, MB). For patient AP, both HIH and MB noted the presence of moderate apraxia of speech, with distorted phonemic substitutions and transpositions, distorted vowels, marked additions, substitutions, omissions, multiple attempts at words with inconsistent production across attempts, increasing difficulty with phonemic

complexity and word length, and abnormal prosody (described as monopitch). Speech output was diminished, and short sentences were interspersed with long pauses. Speech was also mildly dysarthric and characterized by reduced breath support with monopitch and monoloudness, errors in speech sound production, and mildly reduced voice quality. The Apraxia of Speech Rating Scale – Version 1 (ASRS) (Strand, Duffy, Clark, & Josephs, 2014) score was 30 with 15 items rated. As quantified by performance on the WAB (Kertesz, 2007), the information content of language output was intact and fluency was reduced. Structure was simplified and generally grammatically correct, but there were some instances of mild agrammatism due to exclusion of function words such as “to.” The ability to comprehend and produce both active and passive grammatical statements was preserved. Repetition was impacted by motor speech errors but appeared to be relatively intact with respect to phonological short-term memory. He had no evidence of surface dyslexia or surface dysgraphia, and a modified Pyramids and Palm Trees task assessing for semantic knowledge was normal (15/15).

In comparison, the nfvPPA patient performed similarly on the ASRS, scoring 26 with 13 items rated. His fluency was intact, and his information content was similarly reduced (see Table 2). In contrast to AP, whose syntactic comprehension was intact, the nfvPPA patient performed worse on this task, indicating a greater degree of agrammatism.

Communication evaluation: acoustic analysis

Computer-assisted acoustic analysis was performed on speech samples from AP and the patient with nfvPPA. In addition to standard linguistic tasks including a motor speech evaluation, assessment of spontaneous speech, and reading from a standardized passage (the Grandfather passage), affective prosodic expression was assessed using the ApBat repetition task (Ross & Monnot, 2008; Ross et al., 1997). The task calls for the repetition of a presented series of sounds under three conditions: sentential, monosyllabic, and asyllabic (i.e., decreasing the verbal-articulatory demands). An assessment of affective-prosodic comprehension using sentential, monosyllabic, and asyllabic utterances was also performed over the telephone, 8 months after the production and repetition tasks were done, due to limitations of clinical care.

AP was recorded using the internal microphone on an encrypted 2015 MacBook Pro using version 2.0.5 of

Table 2. Speech and language tasks.

Patient ID	AP	nfvPPA	Norms	nfvPPA cohort ^b
WAB Spontaneous Speech: Information (10)	9	9	10(0) ^a	NA
WAB Spontaneous Speech: Fluency (10)	5	6	10(0) ^a	6.24 (2.59)
WAB Recognition Subtest (60)	60	59	NA	58.40 (4.49)
WAB Command Comprehension Subtest (80)	80	80	NA	66.84 (15.19)
WAB Repetition Composite Score (100)	100	80	NA	80.92 (20.61)
Abbreviated Boston Naming Task (15)	15	15	14.3 (1.1) ^a	12 (2.9)
Syntax Comprehension	22 ^c	17 ^d	NA	NA
Apraxia of Speech Rating Scale (ASRS)	30 ^e	26 ^f	NA	NA
Oral Apraxia (Imitation) (14)	11	7	NA	NA

WAB = Western Aphasia Battery; NA = Not Available; MSE = Motor Speech Evaluation; ^aMonolingual English speaker control values from Milman, Farooqi-Shah, and Corcoran (2014); ^bValues from Mandelli et al. (2016); ^cScore is from short-form version, total 24 items; ^dScore is from long version, total 48 items; ^e15 items rated, maximum score of 60; ^f13 items rated, maximum score of 52.

Audacity® freeware (Audacity Team, 2018) for spontaneous speech and language tasks. The ApBat was delivered and recorded through PsychoPy2 software (Peirce, 2007). All wave files were inspected for noise not originating from the patient, and, if found, noise was manually removed from each file in Audacity. The wave files were then analyzed using Praat software v6.0.29 (Boersma & Weenink, 2018) for differences in frequency and intensity measures. Pitch tracking errors were minimized by adjusting pitch floor and ceiling to the values of $q5*0.83$ and $q65*1.92$, which have been shown to be better estimates of extremes of pitch compared to setting floor and ceiling values at default parameters (De Looze, 2010; De Looze & Hirst, 2008). Frequency measures included mean and standard deviations of fundamental frequency in Hertz. These data were used to calculate the coefficient of variation, also known as relative standard deviation, which has been used in prior publications to assess pitch variation (Ross et al., 1997; Vogel, Maruff, Snyder, & Mundt, 2009). Readings of the Grandfather Passage were also analyzed using a script developed by de Jong and Wempe (2009) which quantifies specific time-based measurements useful in the assessment of apraxia of speech (Ballard et al., 2014).

Results from the acoustic analysis are displayed in Table 3. Both AP and the nfvPPA patient demonstrated various impairments, but there were substantial differences. On the affective repetition task of the ApBat, in which pitch variation was measured using a coefficient of variation percent (standard deviation/mean of fundamental frequency in Hertz multiplied by 100), AP performed markedly worse (z-score = -5.6) on the sentence repetition task, whereas the nfvPPA patient performed normally on the sentence repetition task (z-score = $+0.7$). Furthermore, AP's performance did not change as verbal-articulatory demand was reduced, whereas the nfvPPA patient actually became hyperprosodic during the asyllabic condition, a pattern that may be observed in patients with left brain damage (Ross & Monnot, 2008). Another major difference involved speech timing. Although both patients had impaired speech articulation rates, the rate was substantially lower in the patient with nfvPPA compared to AP. On the affective prosody comprehension assessment, AP showed mild impairment on the sentential task (z-score = -1.8) and incremental worsening on the monosyllabic (z-score = -3.6) and asyllabic (z-score = -3.6) tasks, a pattern that is consistent with right-brain damage, and can be observed in older adults as a normal (age-related) impairment in affective prosody

comprehension (Orbelo, Grim, Talbott, & Ross, 2005). Affective prosody comprehension data were unavailable on our nfvPPA comparison patient.

Assessments of facial expression and oral apraxia

AP's spontaneous facial expressions were closely noted throughout the clinical evaluation. Generally, his spontaneous emotional facial expressivity was flat, although he sometimes spontaneously produced a Duchenne smile, a smile involving the orbicularis oculi in addition to the zygomaticus major (Ekman, Davidson, & Friesen, 1990). Facial expressions were recorded on a Samsung HMX-F90 camcorder during dedicated affective imitation and production tasks. AP was first directed to express a named emotion and was then shown a picture of that emotion and asked to imitate it. Emotions included fear, anger, sadness, happiness, disgust, and surprise. The patient's expressed emotions were then reviewed using slow playback of the video and rated using a previously defined method that correlates well with the Facial Action Coding System (Gola et al., 2017). This method involved a subjective categorization of whether the patient expressed the expected emotion perfectly (2 points), with difficulty (1 point), or not at all (0 points). Following the test protocol, 0 and 1 are combined to 0, and a perfect presentation becomes a 1.

Using standardized assessments, AP was able to approximate a smile, especially when provided an image to copy. The expression of other facial emotions, however, was poorly performed. AP scored 1/6 on a test to produce a facial expression on command, and 1/6 for imitation of facial expression. By comparison, a group of nfvPPA patients was reported to perform at 3.9 (z-score = $+0.5$) for command on this task, and 3.8 (z-score = $+0.5$) for imitation (Gola et al., 2017). We were unable to directly compare AP to our nfvPPA patient as measures of facial expression were not available. We also asked AP to perform a non-standardized assessment of oral apraxia. He was asked to pretend to sniff, blow out a match, cough, whistle, lick an ice cream cone, lick peanut butter off the roof of his mouth, and chew bubble gum. Each item was scored 0–2, which was then scaled as above for comparison. On these tests, he scored 5/7 on both spontaneous and imitation tasks, and 11/14 on a brief oral mechanism examination (investigating basic movements like opening and closing the jaw and moving the tongue). In summary, using a similar scoring schema on tests of putative oral apraxia versus

Table 3. Acoustic analysis.

Patient ID	AP	nfvPPA
Aprosodia Battery: Repetition		
Sentential (mean CoV %)	8.5 (-5.6)	25.94 (0.7)
Monosyllabic (mean CoV %)	10.9 (-4.3)	33.63 (0.8)
Asyllabic (mean CoV %)	11.5 (-4.5)	51.35 (3.9)
Aprosodia Battery: Comprehension		
Sentential (# correct out of 24)	18 (-1.8)	NA
Monosyllabic (# correct out of 24)	13 (-2.8)	NA
Asyllabic (# correct out of 24)	10 (-3.6)	NA
Spontaneous Speech (CoV %)	6.3 (-4.3)	4.92 (-3.9)
Grandfather Passage (CoV %)	4.8 (-4.0)	4.53 (-4.1)
Grandfather Passage: articulation rate (syllable number/phonation time)	3.40	1.01

CoV = coefficient of variation, higher score indicates more variation in pitch; NA = not available; z-scores in parentheses calculated from normative data provided in Ross and Monnot (2008).

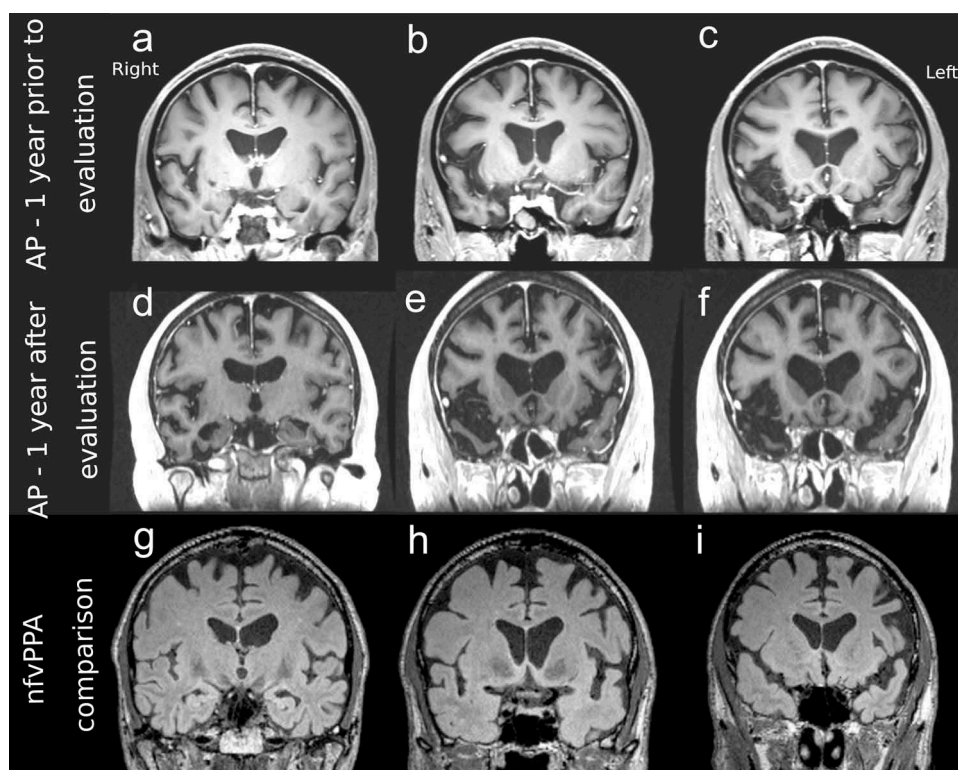


Figure 1. (a–c) 3T MRI T1-weighted coronal images 1 year prior to our evaluation (1 year after motor speech symptom onset) demonstrating right more than left fronto-insular and anterior temporal atrophy. (d–f) 3T MRI T1-weighted coronal images 1 year after our initial evaluation (2 years after motor speech onset) demonstrating progression of right more than left fronto-insular and anterior temporal atrophy. (g–i) A 3T MRI T1-weighted coronal image showing left fronto-insular and perisylvian atrophy. All images are in radiographic orientation.

affective prosoplegia, he achieved 71.4% of the possible points on oral apraxia, and 16.6% of the possible points on affective facial expression.

Neuroimaging

A 3.0 T brain MRI 7 months prior to our evaluation was read as showing mild parenchymal atrophy. However, a detailed review by our group determined that there was striking focal atrophy of the right frontal operculum with mild atrophy of the parietal and temporal operculum and less conspicuous left side involvement in the same areas (Figure 1(a–c)). A repeat 3.0 T brain MRI 1 year after our evaluation found progressive atrophy of the anterior temporal and insular regions with posterior progression, again more striking on the right than the left (Figure 1(d–f)). For comparison, the 3.0 T MRI of the nfVPPA patient (Figure 1(g–i)) showed significant focal atrophy of the left fronto-insular regions mild perisylvian atrophy.

Discussion

We have presented the case of a man with a severe deficit in production of affective prosody and prosoplegia typical of right brain damage, who presented initially with moderate apraxia of speech, in the setting of predominant right fronto-opercular atrophy. As the patient does not meet probable criteria for any known conventional diagnosis, we present AP to illustrate the specific neurobehavioral effects of focal right

frontal neurodegeneration. Detailed analysis of this case, together with contrasts in a case of nfVPPA, leads us to conclude that aprosodia and prosoplegia in AP reflected initial right-sided degeneration that was then followed by left frontal involvement that caused the onset of apraxia of speech, which precipitated his initial clinical assessment.

AP's performance on the ApBat differed remarkably from the performance of a patient with nfVPPA. In left brain-damaged patients with diminished ability to express affective prosody, reducing the verbal-articulatory demands (i.e., moving from sentential to asyllabic tasks on the ApBat) causes a robust improvement in the repetition of affective prosody, as was observed in the nfVPPA case. In contrast, in right brain-damaged patients with diminished ability to express affective prosody, reducing the verbal articulatory demands does not improve their performance, as observed in AP. In addition, AP had poorer mimicry of facial expressions than any performance previously described in nfVPPA (Gola et al., 2017). Our patient's relative sparing of grammar could suggest the presence of primary progressive apraxia of speech (PPAoS; Duffy et al., 2015; Josephs et al., 2014, 2012) type II, which has been characterized as having "loss of prosody." Here it is again important to discriminate if the "loss of prosody" is predominantly linguistic or affective. Because acoustic analyses in PPAoS have focused on timing (Duffy et al., 2015; Josephs et al., 2012) rather than measures of pitch variation, the prosodic deficits described are most likely linguistic rather than affective (Ross et al., 2013).

Given his right frontal and temporal atrophy, one might have expected AP to meet criteria for bvFTD. While his wife noted that he had become less emotionally expressive than usual, both she and the patient denied any other substantial personality changes. He continued to be actively engaged in what he enjoyed doing and showed no erosion in empathy or social graces. He had no obsessions or unusual behaviors beyond a stereotypical contraction of his mouth musculature. Mild executive dysfunction was present, but he met no other bvFTD criteria. Some of his deficits with affective-prosodic comprehension are reminiscent of the right temporal variant of frontotemporal dementia (Binney et al., 2016), especially since and the right temporal lobe has been associated with impaired production and comprehension of affective prosody (Ross & Monnot, 2008; Wright et al., 2016). However, AP's most prominent deficit involved the production of affective prosody rather than loss of comprehension. In addition, the right temporal variant is not commonly associated with apraxia of speech.

If aprosodia and prosoplegia can initially present as distinct syndromes of emotional expression, apart from any altered internal emotional experience typical of bvFTD, what could potentially be interpreted as a personality change may in fact be no more than diminished ability to express emotion, i.e., the difference between not appearing to care versus truly not caring. Atypical nonverbal behaviors due to neurological disease (e.g. hypomimia in Parkinson's disease) have been shown to result in negative first impressions of patients (Hemmesch, 2014), which can adversely impact interpersonal relationships (Pentland, Pitcairn, Gray, & Riddle, 1987). Alterations in emotional displays are critical but may often be missed as more obvious clinical features appear with disease progression, such as aphasia with left fronto-insular involvement, alterations in comportment with spread to ventral regions and the anterior cingulate region, or a movement disorder if the basal ganglia are involved.

Notably, AP was reported as not being particularly emotive at his baseline. This raises the possibility that he may have a premorbid right-hemispheric developmental syndrome, characterized by diminished paralinguistic communication and social deficits in children (Voeller, 1986, 1995; Weintraub & Mesulam, 1983). Such a syndrome may have left him more susceptible to a focal right hemisphere neurodegenerative process, similar to developmental dyslexia's relationship to the logopenic variant of primary progressive aphasia (Miller et al., 2013; Rogalski, Johnson, Weintraub, & Mesulam, 2008).

As described in AP and in similar cases (Confavreux, Croisile, Garassus, Aimard, & Trillet, 1992; Ghacibeh & Heilman, 2003; Graff-Radford, Drubach, Strand, & Josephs, 2012), the clinical detection of aprosodia and prosoplegia may be accomplished by the systematic screening of all patients in whom a neurodegenerative disease is suspected. This goal may be efficiently achieved by asking the patient to imitate a few different emotional phrases and faces. As with screening for language deficits, lower frequency emotional expressions (e.g., disgust) are likely to be of higher yield. If a patient is unable to perform these tasks, a more detailed assessment of the affective communication is warranted.

In summary, we have described a patient with striking focal atrophy of the right greater than left perisylvian regions and temporal lobes, and particularly of the right frontal operculum, who does not clearly meet probable diagnostic criteria for any neurodegenerative disorder, but whose presentation offers unique insights into brain-behavior relationships. Objective acoustic measures indicate relative sparing of common measures of linguistic fluency, but with disproportionately severe loss of the ability to produce affective prosody. Similarly, common measures of oral apraxia were relatively spared, but with a severe inability to imitate emotional facial expression. In concordance with the neuroanatomic understanding of affective communication based on the study of stroke patients, AP has disproportionate atrophy of the right anterior insula and frontal operculum that can plausibly explain his aprosodia and prosoplegia. The presence of perisylvian atrophy in the temporal neocortex may explain his milder difficulties with affective-prosodic comprehension. Apraxia of speech is also present, but in our view was a late development most likely reflecting disease progression involving the left frontal operculum. We have demonstrated techniques to distinguish between affective and linguistic communication, and the detection of aprosodia and prosoplegia even in the setting of other clinical features that may otherwise obscure a patient's earliest and most severe deficits. Whether AP can be diagnosed with primary progressive aprosodia must await further investigation with other similarly affected patients, but his case indicates that including an evaluation of paralinguistic communication as part of a clinical assessment will lead to an enhanced diagnostic understanding of a patient's condition and improve patient care. Thus, we urge clinicians to add an appropriate assessment of paralinguistic communication, including affective prosody and processing of facial expressions, to the evaluation of patients with neurodegenerative disorders.

Disclosure statement

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