The Psychological Reality of ESP Processing: Insights from Aviation English

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Abstract: In the professional environment of aviation where efficiency and safety are fundamental concerns, a language has been created which conforms to both requirements. This is the language of Aviation English: a simplified and specialised subset of English. Speakers of Aviation English utilise a restricted syntax and specialised vocabulary to communicate in a rapid and unambiguous method. With such a rapid exchange of large amounts of information, communication error is inevitable. Examples of speaker failure in aviation include errors in read-back, intelligibility and idiomatic phrases. Examples of hearer failure include accepting a clearance for another aircraft, homophony confusion, and anticipatory actions. While minor errors can result in annoyance and frequency congestion, major errors can have disastrous results. The topic of how to effectively train pilots and controllers in Aviation English is one that is at the forefront of discussions in the industry: incorrect phraseology is not only a problem for efficiency of operations but also an issue of safety, particularly when non-native speakers are involved. This study presents an analysis of language in a series of pilot-ATC voice communications, with particular focus on deviations to standard phraseology. Our analysis highlights the clear need to focus on how violations affect both the speakers and listeners in this English for Specific Purposes (ESP) context.
Keywords: English for Specific Purposes (ESP), sublanguages, language processing, Aviation English

INTRODUCTION

Using and comprehending a specialised language is frequently an integral part of being an expert in a field (e.g. medicine, aviation). Specialised languages have been given a wide variety of names: “restricted languages”, “specialised discourse”, “sublanguages”, “domain-specific languages”, “prescribed languages”, and “standardised languages” (cf. Firth, 1957; Wallace, 1981; Harris, 1982; Kittredge 1982; see also Gotti, 2008 for an in-depth discussion of sublanguage terminology). These languages exhibit specific linguistic features such as specialised vocabularies, distinct lexical classes, controlled syntax, grammatical restrictions, formulaic expressions, and a statistical profile of word occurrences. The conventions for these languages are learned; speakers are taught the prescribed phraseology and rules for communication during their introductory training. Thus, specialised languages can often appear as incomprehensible jargon or lingo to the outsider.

Often this language takes the form of an ESP (English for Specific Purposes) and is taught with a focus on the specific needs of learners within a particular field or occupation rather than general language skills. This requires the speaker to learn, understand, and use special linguistic features such as smaller vocabularies, distinct lexical classes, grammatical restrictions, and formulaic expressions (Gotti, 2008). In the professional environment of aviation, where efficiency and safety are fundamental concerns, a language has been created which conforms to both requirements. This is the language of Aviation English: a simplified and specialised subset of English used in aviation to ensure clear, concise, and unambiguous communication between pilots, air traffic controllers (ATC), and other aviation professionals. It is seen as having two main components: standardised phraseology, which includes the highly prescribed, sublanguage expressions set by the International Civil Aviation Organization (ICAO) and Plain English, which is used when situations go beyond what standard phraseology can cover (e.g., emergencies, unusual events, or clarifications).

Although recent developments in technology have provided the field of aviation with methods in which to improve information transfer, verbal communication remains a critical aspect. In 2011, the International Civil Aviation Organization (ICAO) required participating UN States to implement regulations concerning English language proficiency for all pilots and air traffic controllers who engage in international operations. However, despite a proliferation of Aviation English programmes, materials and tests, a recent UK Civil Aviation Agency (CAA) review states that “...minimum levels of language proficiency as set out by [the ICAO]

are not fully present in international aviation...” (Clark, 2017; see also Emery, 2014). This is due, in part, to a serious lack of ongoing access to analysable linguistic data from air-ground communications. This study investigates the use of non-standard phraseology among aviation professionals through an analysis of authentic ATC transmissions.

STANDARD PHRASEOLOGY

Standard Aviation English Phraseology is the specialised language spoken by aviation professionals in which abbreviation and economy in communication are the goals of effective discourse. Aviation English is domain-specific: it is used exclusively between trained speakers and listeners on dedicated VHF radio frequencies. Speakers of Aviation English share a background of comparable professional knowledge gained through specialised training in the field of aviation. This background knowledge includes (but is not limited to) flight dynamics, guidance, weather terminology, mechanical systems, aerodrome operations, and other operational procedures. The language relies exclusively upon verbal information based upon prior knowledge gained through training and experience. It has a prescribed number and letter readout system, limited syntax, restricted vocabulary, distinctive turn-taking identifiers for speakers and addressees. Even in normal operating conditions, there are special demands placed upon speakers in the aviation environment (e.g. weather, traffic, passengers). The environment is intense, highly regulated, and entirely mediated.

Speakers are encouraged to maintain a controlled rate of speech and use clear breaks between words and phrases (ICAO doc 9835, 2004). They are reminded to avoid blurring of consonants, verbosity, and lowered voice. In order to avoid homophony of some of the more commonly used words as well as to avoid problems introduced by the acoustic similarity of some English phonemes (e.g. [v] and [f]), Aviation English employs a prescribed number readout system. For example, speakers are encouraged to pronounce the number “nine” as “niner”. For similar purposes, a specialised phonetic alphabet (*Alpha, Bravo, Charlie*...) is used for letter readout. Aviation English also employs special words (*Roger, Over*), abbreviations (*ILS, VFR*), specialised jargon (*squawk, swing*), and elisions of longer phrases (*Wilco* for *will comply*, *Ident* for *identify*). Below is an example of a standard exchange between an air traffic controller and a pilot:

(1) Controller: *Delta twenty-one twenty-seven, Boston Tower, runway one five right, position and hold.*
Pilot: *Twenty-one twenty-seven, position and hold, one five right.*

In this exchange, the controller initiates the utterance by addressing the aircraft, designated by a pre-assigned callsign: [Delta twenty-one twenty-seven]. The controller then identifies themselves as the speaker [Boston Tower], instructs the aircraft to manoeuvre onto a specific runway [Runway one five right], and remain in position for take-off [position and hold]. The controller’s instruction [runway one five right, position and hold] has two distinct yet fundamental meanings:

(2) =the airplane may taxi onto the runway.
=the airplane is not cleared for take-off.

The pilot acknowledges this by repeating specific parts of the controller’s instructions: [position and hold, one five right]. This response infers the following information:

(3) = I will enter the runway and assume position for take-off.
= I will not take off until I receive further instructions from you.

Sublanguage theory assumes that the interpretation of their fragments requires reconstitution of the empty spaces provided by deletions (Kittredge 1982: 116): thus, listeners are expected to rebuild the missing parts of the utterance from their own knowledge base, which is made up from experience and learned information. The shared knowledge of this specialised field is a requirement for successful transfer of information. Certain elements of this process are obligatory and others optional, but all utterances must be able to fit into the same 'underlying ...template' each time (Kittredge, 1982). The pilot's readback of instructions is considered to be one of the most important parts of the communication process because errors and misunderstandings can most easily be detected during read-back. This readback is often very condensed, repeating only "raw information" such as numbers, requisite waypoints, taxiways, or navigation instructions.

Sentence structure in Aviation English is notably constricted, to the point where utterances would qualify as ungrammatical or deviant in natural language. And while normal utterances in English present primarily in the SVO (subject-verb-object) order, utterances in Aviation English not only exhibit random word order, but this order can change without the meaning of the utterance itself changing. Both constructions in Example 4 are considered acceptable phraseology in Aviation English: they carry the same meaning.

(4) *Cleared to land runway one niner right.*
Runway one niner right cleared to land.

This is due to the fact that each component (e.g. [cleared to land] [runway one niner right]) has a specific semantic meaning that can stand alone.

Another syntactic feature of Aviation English is the deletion of pronouns, adjectives, definite articles, auxiliary verbs, felicitations, and other function words. Again, this is primarily ascribed to the need for conciseness and unambiguity in communications. Where these structures have been deleted, listeners are expected to rebuild the missing parts of the utterance from their own knowledge base.

(5) **Pronoun deletion:**
Descent approved.

Definite article deletion:
Say braking action.

Auxiliary verb deletion:
Southwest twelve forty-eight at flight level three niner zero.

Fitzpatrick et al. (1986) view sublanguages not as ill-formed in comparison to standard language, but as reduced forms of standard sentences. In this sense, the sublanguage sentence fragments then provide patterns that can be expected in the sublanguage's domain.

One of the most characteristic features of a specialised language is monoreferentiality: while words (and phrases) can have a wide range of meanings in regular discourse, they are only allowed a single referent (i.e. meaning) in specialised languages (Gotti, 2008). An example of this characteristic can be found in the Standard Marine Navigational Vocabulary, where the word "foul" can only refer to the twisting of a cable, line, or rope around the anchor or propeller. e.g. "my anchor is foul" (International Maritime Organization, 1985). "Foul" cannot be replaced by synonyms (e.g. "tangled") or paraphrasing (e.g. "all wrapped up") because such phraseology is not in the Standard Marine Navigational Vocabulary (cf. Strevens & Johnson, 1983).

As with other specialised languages, monoreferentiality is a key feature of Aviation English due to the need for both conciseness and unambiguity in communications. For example, the words *climb* and *maintain* cannot not be replaced or paraphrased by items such as *ascend* or *remain at:*

(6a) *Climb and maintain four thousand.*
(6b) **Ascend and *remain at four thousand.*

While it may seem excessively stringent, such an error can result in the failure of message transfer, or worse. The utterance in 6b not only violates the need for conciseness, but more importantly, the use of the word "ascend" could be confused with the opposite instruction "descend", resulting in a devastating outcome for an aircraft. On December 16, 2012, a private pilot was conducting an instrument approach to an airfield in South Carolina, United States, when he experienced directional instrument failure. He advised the controller that he was "no gyro" (i.e. without gyroscopic flight instruments such as a compass) and requested an alternate airport which had better visibility and thus would be a safer option for an approach. However, the implications of "no gyro" were unclear to the air traffic controller, who directed the pilot to make another instrument approach- the pilot lost control of the aircraft on approach and crashed (ASR-16-004, 2016).

Elaborate planning is required for certain types of discourse (cf. Levelt, 1989). In terms of cognitive linguistic processes, aviation communication requires near-instantaneous speech recognition and production: listeners must understand and respond to the information provided by speakers as fast as possible. Pilots must listen to the commands issued by the controller, repeat the required components, and follow the instructions. Furthermore, an air traffic controller or ground controller can be in contact with any number of aircraft at one time, often issuing instructions and commands in a rapid, successive order. The limitations on human cognitive ability are significant in high-stress situations: decision-making strains the capacity of short-term memory and language processes (Lindsay and Norman, 1977). In such conditions, both the production and processing of language is taxed by concurrent non-verbal tasks, stress, and decision-making (Helmreich et al., 2001). It has been shown that the grammatical processing capacity diminishes when the subject is engaged in concurrent motor, linguistic and cognitive tasks (Blackwell and Bates, 1995).

High workload in any form of non-verbal tasks puts strain on language processing and production (cf. Kubose et al., 2006; Schwalm et al., 2008), resulting in errors and failures for both speakers and listeners. Examples of speaker failure in aviation include errors in read-back, intelligibility, and idiomatic phrases. Examples of hearer failure in aviation includes mishearing instructions, homophony confusion, and anticipatory actions. On April 26, 2024, pilots of a Southwest Airlines flight were cleared for take-off while a United aircraft was crossing the active runway. ATC instructed the United crew to "Taxi via Taxiway E, hold short of runway 18L"; however, the crew read back "Taxi via Taxiway E, and cross runway 18L" (AIR-24-02, 2024). Neither the controller nor the crews caught this error and Southwest Airlines was forced to abort take-off at 110 knots ground speed. This was a clear error of expectation bias in sentence comprehension and production.

PLAIN ENGLISH IN AVIATION: A DESCRIPTIVE STUDY

When situations go beyond what standard phraseology can cover, governing aviation bodies have also recognized the need to utilise non-standard language (ICAO doc 9835. 2004).To illustrate how this unfolds in practice, the following sections contain examples drawn from authentic ATC transmissions of nonstandard situations in the aviation environment. Broadly speaking, there are two types of aviation communication: intra-cockpit (CVR) and

ground-to-aircraft (ATC). CVR data takes place on the flight deck or cockpit: these communications are less formal and more conversational, lack standard phraseology, and can range in topics from weather reports to the current political or economic situation. In contrast, ATC communications are conducted by pilots, controllers, and other operational personnel (e.g. ground staff) using Aviation English on VHF radio frequencies.

The field of aviation is highly regulated by government or government-contracted agencies. Access to data remains one of the largest and most immediate problems for undertaking a study of aviation communication. Information is strictly controlled and outside access for academic or public purposes is often restricted. Data can be collected in two ways: either by obtaining the reports published by the overseeing agency, or by accessing the audio recordings. Hundreds of hours of archived ground-to-aircraft (ATC) communications are available in the public domain on LiveATC.net, including recordings of transmissions made during nonstandard operations. The data we present comes from both of these sources. It spans the last fifteen years and contain accounts of emergencies, incidents, serious incidents, lost navigation and other non-natural situations (earthquakes, no clearances, fires in ATC tower, bird strikes, lost cargo, and pilot incapacitation).

LINGUISTIC FEATURES OF NON-STANDARD PHRASEOLOGY

A coded sublanguage can only cover so many topics until it is exhausted: in the case of standard aviation English, it is so limited that almost all nonstandard situations require a shift in language. Incident reporting databases are littered with references to ambiguous, confusing or inappropriate language use. Natural language features creep back into non-standard communications and emergency transmissions. While Standard Aviation English is marked by restricted syntax and vocabulary, non-standard phraseology in aviation communications can contain vague language (Example 7) code-switching (Example 8), elisions, fillers, poorly pronounced sounds, and slang (Example 9):

(7) *Negative, we're okay.*
Affirm, he's bust his level?
Air One nine three seven where are you?

(8) *Taxi approved Scandinavian 001. Vad har du för bankonditioner just nu?*
Do you want to "divva" and land at Malmö- Sturup instead of Borås?
華信 eight three eight 塔台

(9) *Whatever you need- just get 'em down.*
Roll the equipment- we're goin' off the end.
Got some funky winds up here..
That's affirmative let's break off, can you put us back in the pack?
Ah roger, and how was the ride?

Nonstandard language in aviation is peppered with false starts, ungrammaticalities, and fragments. Studies of cognitive load and speech have revealed patterns in pauses, hesitations, articulation rate, number of syllables, response latency, sentence fragments and content quality (Le et al., 2011). The speaker's focus is no longer on standardizing utterances and communication success, but on problem-solving and risk analysis. Often times the situation calls for more generalized language simply because the pilots do not know the full nature of the problem:

(11) *Uh we're having a little uh we nee- need to run a check…*

Lexical replacements (homonyms and synonyms) also occur with greater regularity:

(12) *and uh how much gas you have- fuel you have-*
uh, smoke in the cockp... smoke in the cabin.

Another noticeable feature of nonstandard phraseology is the use of indirect speech acts and utterances requiring pragmatic competence. Indirect speech acts as defined by Searle (1975) are "cases in which one illocutionary act is performed indirectly by performing another" (60). Nonstandard communications by both controllers and pilots are peppered with these types of indirect speech acts:

(13) *If you can give me fuel and souls.*
And can you say what your uh, tail number is?
When you're able uh can you say the uh say the nature of the emergency?
If you could climb back up to two thousand five hundred please and turn right now onto one two zero degrees.

Minimizing words, e.g. *just, little, a bit*, and *slight* also feature in the language of nonstandard situations:

(14) *We have a minor problem.*
We've got slightly more smoke in the cockpit now, so we'd like to make this into a MAYDAY please.

Such communicative acts are grounded in politeness strategies, social goals, and communal expectations (cf. Clark, 1979). They often employ pragmatic devices such as inference, referring devices, idioms, minimizing language, and felicitations:

(15) *Victor Golf Echo if you could just advise us total on board please if you could.*
Er we have five P.O.B. Sir, we're coming straight back round we'll join erm... left hand coming straight round for two one, if that's OK.

In this exchange (Example 15), the pilot has requested to return to the airfield due to an engine problem. The controller requests the total number of passengers on board the aircraft without using an imperative: *if you could just*. This indirect request, combined with the minimizer *just*, injects a sense of politeness and desire to help into the utterance. The politeness is further magnified by the closing of *please if you could*. By making directives into requests, the degree of compliance becomes optional.

However, this type of communication can result in ambiguity and confusion across different language communities. In 1990, Avianca Flight 52 experienced a fuel emergency after holding over New York due to bad weather (cf. NTSB/AAR-91/04, 1990). After being forced to execute a missed approach and minutes before the engines failed due to fuel exhaustion, the following exchange took place between the L2 pilot and the L1 controller:

(16) Avianca 52: *... and, ah, we're running out of fuel, Sir.*
Controller: *Is that fine with you and your fuel?*
Avianca 52: *I guess so, thank you very much.*
Captain: *Digale que estamos en emergencia (Tell him we have an emergency)*
First Officer: *Si, senor, ya le dije. (I already told him, Sir)*

First Office to Controller: *We'll try it again, we are running out of fuel.*

Despite the Captain telling the First Officer to declare an emergency in Spanish, at no point did he use the standard Aviation English phraseology in the air-to-ground communications. Instead, the phrase running out of fuel resulted in an ambiguous transfer of information: the controller inferred the situation as a non-emergency; that is, a plane low on fuel, but with sufficient reserves to land. Secondly, the controller used non-standard phraseology by asking, *is it fine with you and your fuel?* Both messages failed to be understood by the members of the conversation. Minutes later, with the reserve fuel supplies exhausted, the engines flamed out and Avianca Flight 52 crashed into a small town on Long Island. Seventy-three people died.

Our corpus shows similar issues from an interaction at Chicago's O'Hare International Airport in 2010, when a ground controller informed a LOT Airlines pilot that their brakes were emitting smoke:

(17) Controller: *and uh Lot three heavy, uh you might want to pull into the pad, you've got smoke coming off your brakes.*
[no response]
Controller: *Lot three heavy, just stop JUST STOP just-*
Pilot: f*ive three stop.*
Controller: *you've got- your brakes are on fire. your left- looks like your left main brake is on uh smoking... on fire.*
Pilot: *thank you.*

The pilot, an L2 English speaker, does not respond to the controller's observation you might want to pull into the pad; in fact, there is no response until the controller issues the JUST STOP command. This is an example of an indirect speech act failing: the L2 pilot cannot access the underlying message of the L1 utterance, which is to stop the aircraft due to smoke coming from the brakes. This exchange highlights two major issues in aviation language. The first is the prevalence of Plain English use by American aviation professionals. L2 pilots regularly report that conducting flight operations in America is more difficult than other English-speaking environments due to the use of slang and Plain English on the radio:

(18) Pilot: *Just FYI you might wanna ask that American fifty seven just landed before the Delta what happened to him.*
Controller: *American six forty eight are you uh with us? … why, did you see something that I didn't see?*
Pilot: *Uh just United 53 he looked pretty exciting about to land 300 feet.*
Controller: *Alright we'll ask him thank you.*
Pilot: *Alright he's probably on Ground.*

Nevertheless, it has been argued that the use of Plain English can facilitate in "situational awareness" by providing more information than would be present in standard aviation language. It has also been suggested that Plain English "contributes to the local coherence and effectiveness of the interactions" (Moder and Halleck, 2009). One example in our corpus comes from New York's La Guardia airport, after an Aeromexico crew executed a 'missed approach' procedure due to high winds. The crew experienced turbulence and wind shear on the climb out of the airport. The airplane, equipped with an onboard wind shear detection system, issued a warning to the crew.

(19) Controller: *Aeromexico four oh two, fly heading one three zero and uh maintain two thousand. ....*
Aeromexico 302: *negative, we are continue climbing... uh we can... we continue with the wind shear.*
Controller: *ok what altitude do you need to climb to?*
Aeromexico 302: *uh, six thousand.*
Controller: *Maintain present altitude for now, I can't uh clear you up to that high at this moment.*
US Airways: *Tower, he has a wind shear warning. He's fighting that, so he'll do what he has to do.*
Controller: *Roger.*

In this situation, the controller did not understand the gravity of the situation until another pilot on the frequency explained to them, in Plain English: *he'll do what he has to do.*

Despite the drive to implement the use of standard phraseology, it has become clear that features of Plain English creep back into transmissions in a myriad of ways. Our corpus materials have shown evidence of minimizations, justifications, elaborate syntax, indirect speech acts, felicities, lexical swaps, jargon, slang, misfires, anticipation and transposition errors all feature in the transmissions. On one side of the argument, the use of plain language is considered unacceptable, licensed with degrading information transfer and clogging the airways. However, when events occur outside the normal operating expectations, the ICAO also recognizes the need for plain language use:

> "It is not possible, however, to develop phraseologies to cover every conceivable situation. When plain language is required, it should be delivered in the same clear, concise and unambiguous manner as phraseologies, for example, in emergencies or unusual situations." (ICAO doc 9835 2004: 2.4)

Such a specialised code of communication cannot cover all possible outcomes during flight operations. The qualities that make standard Aviation English a safe and efficient method of information transfer can also limit it in certain situations.

However, while Plain English may contribute to effective communication between native English speakers, this is not always the case when the exchange involves a non-native speaker of English. L2 speakers may experience difficulties with Plain English in aviation because, unlike standardised ICAO phraseology, Plain English is spontaneous, often incorporating idiomatic expressions, informal wording, or reduced forms that fall outside the scope of training materials. This unpredictability is compounded by variation in accent and pronunciation, which can further challenge comprehension for those accustomed to more neutral models of English. In addition, the cognitive load of processing unexpected language in real-time, high-stakes situations can hinder understanding, particularly when speakers must prioritize safety-critical tasks. Farris et al. (2008) studied the effects of cognitive workload on L2 speakers during a simulated pilot task and found that high workload was directly associated with the production of dysfluencies (Farris et al., 2008). They also found that L2 speakers depart from more comprehensible speech during times of high workload. Our corpus shows evidence of this:

(20) *OK, please..uh..please uh..ground fire. We have wheel fire, please uh.. have fire assistance, please.*
Now your engine have a smoke coming out.
We may have strike some landing.. some runway edge lights right hand side.

Yeah, we are short of fuel and we are requesting to proceed direct.

Finally, because many aviation training programs emphasize phraseology over extended conversational competence, L2 speakers may not have sufficient exposure to the range of linguistic forms that arise in authentic air traffic communication. Thus, the question arises, how do we teach Aviation English to L2 ab initio pilots and controllers in the most comprehensive yet economic manner?

DISCUSSION AND FURTHER STEPS

The structure of expert language (hierarchies, categories, abbreviations) reflects the way knowledge is organized cognitively. Listeners are expected to rebuild the missing parts of the utterance from their own knowledge base, which is made up from experience and learned information. Flight operations require a complex interaction of different types of professionals (pilots, ATC, ground crew, maintenance personnel). An expert's lexicon is a deeply interconnected, hierarchically and conceptually organized network of terms that supports rapid retrieval, problem-solving, and flexible use, reflecting both declarative knowledge and procedural expertise. In aviation, an expert's lexicon is a tightly integrated network of terms tied to aircraft systems, procedures, and decision-making contexts. It enables pilots to translate verbal input into precise, often automatic actions, reflecting deep understanding and task fluency.

Nonstandard phraseology is not only a problem for efficiency of operations but, more importantly, an issue of safety – particularly when non-native speakers are involved. The evidence from the transmissions above shows that deviations from standard aviation phraseology follow distinct patterns closely linked to specific linguistic structures in English. If linguistic violations in standard Aviation English cause significant responses in the brain of the native speaker, what might they do in the brain of the non-native speaker? Non-native English pilots regularly report that conducting flight operations in America is more difficult than other English-speaking environments due to the use of slang and Plain English on the radio.

There is a crucial need for informed and efficient scholarship focused on nonstandard aviation communication. Currently, the field of Aviation English research is lacking in hard evidence on the impacts of deviations from standard phraseology on the brain. Technological advances in psycholinguistic and neurolinguistic methodologies (e.g. online behavioural experiments, eye-tracking, and brain imaging) are becoming increasingly accessible, creating more opportunities for effective research collaborations. By identifying brain responses that reflect what violations in standard Aviation English do to language processing in the expert comprehender, we can provide objective information for a more precise prediction of the ways operators, testers and trainers in the aviation industry may possibly be failing in achieving their goals.

CONCLUSION

Prior research in language assessment has proven that the creation of training and assessment materials from lexical indices derived from spoken corpora results in significantly more reliable and valid assessments, indices which are not presently extant for Aviation English. If we can establish precisely what the psychological effect of these deviations are on the comprehender, we can use these findings to help structure curricula and assessment protocols. We would expect this data to provide crucial evidence that "the expert brain" is cued to use special (expert) information when processing specialised language, and that violations in the standard (expected) language have deliberate and compelling effects in these listeners. Thus, not only can this research inform theories of how we process language based on

contextual information provided in a sentence, but it can also lay the foundations for extensive further study in various facilities across different countries and lead to the development of wider awareness across the industry. This approach can also help ensure that industry standards remain ahead of technological and procedural shifts: when regulatory bodies and industry associations witness real-world data backed by expert validation, they may be more likely to adopt and enforce standards that bolster safety and interoperability across global aviation sectors. When combined with real-world evidence, this can lead to more nuanced assessments, improved instruments, and adaptive algorithms used in language testing.

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