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Intonation and Fluency in Emotionally Dysregulated French Patients with an Acquired Brain Injury: Case Studies

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Abstract

Acquired brain injuries (ABI) often result in persistent emotional dysregulation. As part of a larger study, this paper explores the effectiveness of a dialectical behaviour therapy (DBT) programme, a type of evidence-based psychotherapy that helps patients build emotional regulation skills.

Current literature suggests that a significant proportion of disfluency, faster speech rate and large amplitudes in frequency variation may denote high emotional activation in speech. However, identifying emotional regulation remains a challenge, as dysregulation may manifest as emotional apathy in addition to extreme activation. This complicates establishing a direct link between intonation patterns and emotional dysregulation.

Two ABI patients were recorded in 40-90 minutes semi-directive interviews, in which they narrated emotionally charged memories and described pictures. One patient was recorded five months prior to and immediately before beginning the therapy programme (t0-t1), and the other before and after the five-month programme (t1-t2).

Our findings highlight more variation in intonation at t1 for both patients, and the patient who followed the programme decreased his speech rates over time. These may be indicators of the therapy's effectiveness. Moreover, our results suggest that the ratio of disfluencies may not be a good indicator of emotional dysregulation in ABI patients.

Index Terms: Fluency, Disfluencies, Emotion Dysregulation, Clinical Linguistics, Intonation, Speech Rate, Prosogram, Acquired Brain Injury, French.

1. Introduction

An acquired brain injury (now ABI) can be the consequence of various medical conditions. Aside from the obvious need to reacquire motor functions, most patients and their families report long-term severe behavioural issues, depressive symptoms, and suicide attempts. Patients often say they do not feel like themselves anymore and do not recognise themselves when experiencing behavioural issues [1].

Emotional regulation is the ability to mitigate one's own emotional behaviour when it tends to be impulsive or situationally inappropriate [1], [2], [3]. Emotional dysregulation is a difficulty in identifying, initiating, modulating, and regulating one's emotional expression [1]. Some patients sometimes have extreme emotional responses because they lack the necessary inhibition skills. ABI patients also may have a low emotional awareness: they may be unable to feel, identify and express emotions. This can lead to feelings of emptiness and impaired judgment, what literature refers to as *alexithymia* [4], [5], [6]. While being common in ABI patients, emotional dysregulation is not specific to ABI [1]. Dialectical behaviour therapy (DBT) [1] is a type of psychotherapy based on cognitive behavioural therapy (CBT) [2] in which

acceptance and mindfulness are central. Through reacquiring emotional skills, patients commit to building *a life worth living*. The GREMO therapy (GREMOLCA project, Groupe de Régulation Emotionnelle Lésion Cérébrale Acquise at EMOI-TC, UGECAM Alsace [7], [8]) is an extensive, tailored psychotherapy programme which includes both individual and group therapy, as well as tutorials, homework, and self-rated questionnaires, and is based on Linehan's DBT [1]. Our paper is part of larger study [9] aiming to evaluate the effectiveness of the therapy, and approved by the IRB CPP IDF-XI on the 18/05/2022.

2. Literature Review

2.1. Emotions

Emotion is an intrinsically subjective phenomenon that serves motivational functions, such as inciting learning or socialising. It allows for an overall great adaptability for human beings [10]. It can be considered the sum of the following components: sensation, neurophysiological activation, motor expression and action tendencies which are translated into cognitive and communicative processes, like behaviour [2], [11], [12], [13]. Besides, the lack of consensus on the definition and taxonomy of emotions further complicates the objective study of their expression. This leads to varying and more or less strict acceptations [14], therefore, labelling emotions linguistically is a real challenge. However, the aim of the present work allows for a wide range of the expression of emotion-adjacent phenomena, such as moods, interpersonal attitudes, and character traits. In fact, a broad definition better meets our objective of identifying unintentional emotional expression in the patient's speech: when it is not correlated to explicitly expressed emotion, it could be emotion dysregulation. It is believed that reminiscing is similar, if not equal to the original emotional experience [5].

2.2. Oral Speech and Fluency

Silent pauses illustrate how a prosodic element must be studied as a complex oral phenomenon: one cannot ignore that it is a syntactic component with specific expectations of acceptable distribution [15]. Silent pauses possess a segmentation role that is delimitative, which is an inherently syntactic role [16]. Furthermore, the pause is central to evaluating someone's fluency, and the distribution of disfluencies relies heavily on pauses [17], their durations, and contents: a filled pause may be considered disfluent, and a silent pause may be expected after a voiced hesitation.

Perfect fluency does not exist in the flow of speech [18], [19], [20], [21]. But it establishes a norm under which speakers are effortless to understand for listeners [18], where speech remains intelligible. The concept of fluency is a specific prosodic dimension [18], especially regarding *phonetic* and *syntactic* fluency.

Although the presence of disfluencies is common [16], [18], [22], [23], their presence in large quantities and in specific syntactical positions remains a reliable indicator of a potential clinical interfering with the patient's speech [23]. For instance, in fluent speech, silent pauses are found in between syntactical segments (sentences, syntagms and words), rather than in the middle of them [24]: besides pathological cases, nobody breathes in the middle of a word. As such, pauses interrupting the syntactical order may be considered as disfluencies, as they are *syntactically disruptive*. The topology of disfluencies includes various phenomena:

Voiced hesitations like [ə] or [əm] are prevalent disfluencies in French [16] and may be defined as a non-lexical, non-significative voice intrusion [18].

Prolongation of phonemes, especially vowels, may also take part in the speaker's formulation work. Abnormal vowel prolongation is considered between 180 ms and 220 ms [16], and is not used as a way to intentionally serve linguistic purposes such as saliency.

Repetitions of a short X segment are also considered a disfluency, where X₁ is the repeatable segment, and X₂ and eventual X₃ are the repeated segments [20], [29] (other than stylistic or linguistically intended). *Revisions* have a similar form, where X₁, the *first* or *false start*, is a segment such as a syntagm, and is meant to be replaced by the *new start* Y₂ [23], [26]. Although Candea's [16] definition is limited to occurrences where Y only revises a single phonetic or morphological trait of X, we believe revisions may also appear under a larger definition where X may be any incomplete structure, as Blanche-Benveniste suggests [23].

ABI-specific stuttering caused by anoxic myoclonus may be common in ABI patients [27]. However, such stuttering is scarce in our corpus. This may be survivorship bias since patients selected for the programme may have had time to regain control of their stuttering (see timeline).

2.3. Expression of Emotions in Voiced Speech

Several studies underline how voiced speech is able to convey emotion through communicative functions [12], [28], [29]. Prosody carries out extra-grammatical functions, and some have referred to an *expressive function*, in which attitudes, affect and emotion are expressed [30]. Furthermore, "speech communication conveys more than the syntactic and semantic content of sentences" [14]. Overall amplitude and local perturbations in fundamental frequency appear to be correlated with emotional state [31]. A link can indeed be established between certain intonational patterns and communicative functions; thus, they may also be able to convey emotions [26], [28], [32], [33]. In this case, high levels and a high degree of variation or dispersion would reflect a rather activated emotional state such as anger, and vice versa. The presence of unusual patterns and data for a speaker can also serve as emotional markers. Based on this, voice emotion may express emotional activation. This subjective and affective role played by prosody is largely accepted [29]. In addition, emotions have an impact on the speaker's physiology (heart rate, breathing rate, etc.), on which prosodic parameters such as frequency are largely reliant [34]. A speaker may not necessarily be aware that they are expressing emotions. Consequently, the expression of emotions via the organisation of oral discourse may be unintentional [27], [33]. Fluency may also provide information about a speaker's emotional state: a faster rate would be linked to greater emotional activation and a slower rate with sadness,

for example vice versa [18]. Pauses can also be used stylistically to express emotion [16]. Furthermore, vocalized hesitations show the speaker that he or she may be troubled or emotional [16].

2.4. Objectives and Hypotheses

We aim to assess the speech of patients to determine how it may have changed with or without the therapy programme. Our hypothesis is that a better emotion regulation should manifest through speech, including intonation and fluency. A less disfluent speech could mean better regulation. Though emotion activation can manifest in high amplitude of pitch variation, the link between intonational patterns and emotion dysregulation may be tougher to establish. Since emotion dysregulation can manifest as both extreme emotions and a lack thereof, expression of emotion dysregulation in prosody could be challenging to grasp. Preliminary results from previous work [35] suggest a decrease in speech rate when comparing patients in time, as well as a reorganisation of their fluency, favouring silent pauses and prolongations instead of previously favoured hesitations and repetitions. Greater fluency in their expression of feelings could mean progress in their emotional skills.

3. Methodology

3.1. Obtaining the Corpus

3.1.1. Timeline of Recording

Once a patient is enrolled, the first interview is recorded (t0), after which they go through a baseline phase of five months without the GREMO therapy. The second interview is then recorded (t1), right before the intensive five-month therapy 'semester' starts. The patient is then interviewed a third time (t2), after the therapy ends. Self-rated questionnaires are filled each step: DERS-16 [36], [37] QOLIBRI [38] (see table 3). Some patients also follow speech therapy. Recordings are made to encourage relatively spontaneous speech from patients on several topics, and include several speech tasks, such as reminiscing memories of emotional situations, or describing pictures.

3.1.2. Corpus Characteristics

Our corpus consists of two randomly selected pairs of recordings of two individual patients – either t0-t1, or t1-t2 –, which we transcribed and annotated before analysis. Our findings may not be representative of the whole cohort of patients.

3.1.3. Material and Tools

Patients are recorded in a calm consultation office at the trauma recovery hospital, on a recorder in *.wav format using a directional clip-on microphone (Audio Technica AT831R Cardioid Condenser Microphone) fixed to a lanyard marked with a black felt-tip line. This ensures comparable pitch and intensity values across patients by making the mic-to-mouth distance between recordings roughly the same.

3.1.4. Blinded Characteristics

Data annotation and analysis are carried out blind, which means that we ignore when the recording takes place, and whether the patient has been through the therapy programme yet. This information is later revealed to further compare individuals in our analysis. After lifting the blinding, we can link recordings 002 and 014 to a single individual, as well as 005 and 007 to another individual. 007 was recorded at t0, 005

& 014 at t1, and 002 at t2. Both patients are male and sustained severe traumatic brain injury with diffuse brain damage. 014-002 acquired it as a child (see table 1).

Table 1: *Patient Demographics and Scores*

Patient	Age	Age at BI acquisition	Occupation	Step	DERS	QOL
007-005	65	54	Retired	t0	61	62
				t1	55	55
				t2	37	74
014-002	24	7	Permanent working inability	t1	56	37
				t2	48	47
				t3	31	59

3.2. Processing the Corpus

The audio is transcribed using predefined guidelines and XML tags to standardise the processing of a corpus shared amongst several researchers. Some tags serve the purpose of guaranteeing patient confidentiality. Webmaus [39] is used to align the text to the audio, phonetically transcribe and segment the speech into phonemes on a *.TextGrid file, where fluency is annotated manually through Praat [40]:

Table 2: *Annotation labels used*

Label	Explanation
PSIL	Silent interruption in speech (incl. organic noise)
PNS	Pauses disrupting syntactic dependencies
HES	Voiced hesitation (<i>ehh, euhm, mh</i>)
REP	Any X ₂ segment that repeats an X ₁
REV	Any Y ₂ segment that revises an X ₁
VLN	Long final vowels followed by pauses
ALL	Any phoneme \geq the speaker-specific threshold

The speaker-specific threshold is the mean VLN plus one standard deviation, based on Candea’s methodology [16].

3.3. Measures Carried Out

Syllables are counted using the number of vocal nuclei: in French, one vowel equals one syllable and vice versa [41]. The articulation time is the sum of the vowel and consonant duration; adding the duration of the pauses, including non-syntactic ones results in elocution time. Articulation and elocution rates are calculated by dividing the number of syllables by articulation and elocution time in seconds. The proportion of both silent and non-syntactic pauses is a percentage of the time they occupy in total elocution time; the percentages of vocalised disfluencies are based on articulation time. The *fluent* speech proportion is articulation time minus duration of vocalised disfluencies (see figures 1-4). Prosody and intonation are visualised through Merten’s prosogram representations [42].

4. Results

4.1. Speaker-Specific Locality

Table 3: *Corpus characteristics Grouped by Patient*

Tape n° and step	Recording time (hh:m)	Elocution time (min:sec)	Total syllables
007 t0	0:18	09:08	1695
005 t1	0:34	17:10	4566
014 t1	1:11	58:36	8104
002 t2	1:17	56:55	6718

Our first observation is the variation of recording time despite an identical interview outline containing a specific number of questions. It would seem the duration of the recording heavily relies both on the patient’s locality and fluency: some patients do not have much to answer, or do not go into much detail, and others struggle to enunciate their thoughts. This is proportionally extended to the spoken time and number of syllables produced (see tables 3 & 4).

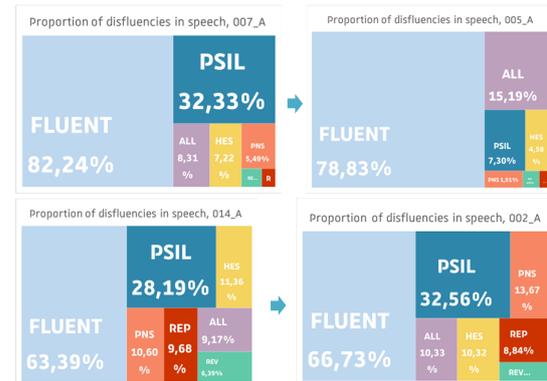
4.2. Elasticity Between Elocution and Articulation Rates

Table 4: *Speech Rates Grouped by Patient*

Tape n°	Articulation time (min:sec)	Art. rate (syll/sec)	Eloc. rate (syll/sec)
007 t0	05:41	4,30	2,67
005 t1	15:37	4,88	4,43
014 t1	35:52	3,77	2,30
002 t2	30:37	3,66	1,97

We notice a significant gap on recordings n°002 & n°007 between the speaker’s articulation and elocution rates, suggesting that pauses take up much more “space” within the speaker’s speech than on recording n°005, for instance (results are rounded to two decimals). When comparing patients’ rates, it would seem to be subject to a varied distribution, suggesting that speech rates are highly speaker-dependent parameters in ABI patient population. Previously obtained values in other ABI patients indicated a decrease in both speech rates [35]. This phenomenon may indicate a better emotional regulation. In any case, slower speeds allow greater communicative effectiveness, including emotional effectiveness, since it is easier to understand patients if they speak slowly. This trend is maintained by patient 014-002’s decrease in speech rates over time. However, patient 007-005’s slightly increased speech rates at t1 contradicts this trend. The vowel durations of both pairs pass Student’s T-test of statistical significance ($p < 0,005$). Such distribution may benefit from being compared to control speaker values.

4.3. Disfluencies as Formulation Work Strategies



Figures 1, 2, 3 & 4: *Proportion of disfluencies in recordings*

Each speaker has his own strategies when organising speech and doing formulation work. The patient on tape n°005 favours prolongation of phonemes as well as silent pauses and voices his hesitation to a lesser extent. Though repetitions and revisions do not occupy a significant proportion of discourse time (Figs. 1-4), patient n°014-002 produced 620 repetitions and 285 revisions at t1 and 314 repetitions and 30 revisions at t2. Patient n°007-005 at t0 produced 10 repetitions and 7 revisions, and 21 and 13 at t1. Patient n°007-005 at t0, as suggested by his slow elocution rate, uses pauses a lot more than at t1, to the point where syntactic breaks are prevalent, as well as prolongations and voiced hesitations.

Both patients decreased in their proportion of fluent speech: patient 007-005 regressed -3,41% from t0 to t1, and patient 014-002 regressed -3,34% from t1 to t2. They also both increased in vocalised disfluencies (respectively +3,41% and +3,34%), although n°007-005 only increased in prolongations (+6,88%). N°014-002 used the opposite strategy and decreased his prolongations -1,16% in favour of slight increases in other

voiced disfluencies. When comparing both patients at t1, patient 007-005 vocalizes his disfluencies 12,10 % less than the other patient, indicating that he is slightly more fluent. On the other hand, patient 014-002 uses silent pauses 25,26 % more and non-syntactic pauses 11,76 % more than patient 007-005. These findings confirm that speech fluency strategies and preferences for certain disfluencies are unique to each speaker, though similarities may be noted. The increase in disfluencies in both patients raises doubts about the reliability of disfluencies as an indicator of emotional dysregulation.

4.4. An Evolution in Intonation

Despite the emotionally reminiscing nature of the interview, the intonation on recording n°007 (t0) can be described as overall flat and monotonous, aside from a few exceptions. For example, the patient’s answers the question about his awareness of the consequences of his lesion. The f_0 values vary little, with one of the most notable variations rising from 114 Hz to 139 Hz on the word “aggression”, which is explicitly emotionally connoted. The biggest variation is at another moment, when mentioning their niece and her quirky vocabulary typical of her childness: “et après on ferme la boutique” (*and then we close shop*). Such variation in the intonation’s amplitude may be justified by the presence of indirect speech that amuses the speaker. Furthermore, when the patient contextualises the scene, a rise from 126 Hz to 152 Hz is observed. In most of their answers, the patient’s intonation is linear and constant, whether they’re talking about other disagreements with their spouse, venting about cars parked on the bicycle lane, or describing Van Gogh’s room.

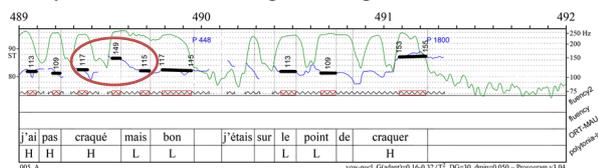


Figure 5: Prosogram of Recording n°005 about an argument.

The recording of the same patient in t1, n°005, seems less monotonous. When describing an argument with their spouse, the patient’s intonation on the segment “j’ai pas craqué mais” (*I didn’t break down, but*) can be seen as rising from 117 Hz to 149 Hz, then falling to 115 Hz. When talking about the accident that caused their ABI, and its consequences, the intonation follows circumflex shape that starts at 125 Hz, rises to 153 Hz and falls back to 118 Hz, right on the word *accident*. The same rhythmic group ends on a raise from 132 Hz to 154 Hz.

The frequency in recordings of the second patient, n°014-002, is more varied. The first chronologically is n°014 at t1: the occurrences are wider and there are greater and more varied intonational patterns than at t2. One example is when the patient talks about his mother shouting at him when she’s upset about something that doesn’t concern him: f_0 rises from 126 to 143 Hz. A second example is where the patient explains he sometimes gets upset when his family does not immediately do what he asks. The f_0 reaches values of 118 Hz, then 224 Hz and stabilises at 124-131 Hz before falling to 96 Hz. Similar patterns are present when the patient explains he finds aggravating when someone disagrees with what he says: the pattern has a min value of 121 Hz and max value of 195 Hz.

On the patient’s second recording, n°002 at t2, the patient mentions stress once, and we note a rise from 112 Hz to 148 Hz as well as various disfluencies, namely repetitions and revisions. However, the intonational context of this instance is

relatively flat even though the patient is recounting a stressful anecdote.

For both patients, our analyses show greater variation and amplitude of f_0 at t1 than at t0 or t2. This could illustrate the patient’s journey in reacquiring the skills to identify their emotions as a first step, and then attempt to regulate them.

5. Discussion

We carried out a quantitative analysis of the proportion of different fluency elements in the discourse of our corpus, as well as qualitative analyses of the intonation of the patients in the study. We compared the speech evolution of two patients, one who underwent a therapy programme and one who had not yet. Speech rates were used as indicators of emotional regulation progress, showing the difference in improvement between the two patients over time. The patient who underwent the therapy showed a fall in speech rates from t1 to t2, where the other patient showed a small increase in speech rates. Such evolution could be linked to the fact that patient 014-002 is regaining control of their emotional experience and could indicate that the GREMO therapy programme – combined with speech therapy or not –, is beneficial for them. In this case, a decrease in speech rates suggests better communicative effectiveness, particularly in the expression of emotions. However, changes in speed need to be accompanied by other suprasegmental elements to establish a link between changes in prosody and emotional regulation. Although a reorganization in fluency strategies is notable in both patients over time, further investigation is required before considering disfluency as a reliable indicator of emotion dysregulation. Our results differ from previously obtained results [35].

Prosodic patterns are best interpreted by chronological comparison. A monotonous intonation at t1 may be the result of emotional dysregulation. We observed instances of wider variations in intonation in emotional narratives. In addition, intonation evolved slightly from one recording to the next, being more varied and ample in the second recordings. This suggests a more effective communication of the patient’s emotional state and may mean the patient is more emotionally aware which seems to be supported by the decrease in DERS scores and increase in QOLIBRI scores. We may experiment ways to quantify intonation evolution as well as standardise f_0 values for cross-individual comparison. Whether this implicit expression of emotion is congruent with an explicit expression through words needs to be verified. Ideal emotional regulation would indeed involve explicit mention of the patient’s feelings. The annotation of explicitly expressed emotions associated with different segments of our corpus will enrich our prosody and fluency results by providing comparable data on chronological evolution. It will also be interesting to compare our results with those of recorded control speakers as to differentiate the speech of emotionally dysregulated people from that of healthy subjects. Finally, we may benefit from comparing both patient’s t2 recordings once they are both transcribed and annotated.

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