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Treatment of Aphasia with Melodic Intonation Therapy in Tone Languages

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1 Introduction

Aphasia is one of the most devastating language disorders, since, in its severe form, it greatly hinders language production or perception – or both. However, aphasia comes in many shapes and it is only one specific condition that is the subject of this paper: nonfluent, or Broca's aphasia. A patient diagnosed with Broca's aphasia exhibits major difficulties with language *production*, but can still comprehend language with ease. In virtually all cases, Broca's aphasia is caused by unilateral damage to the left hemisphere of the patient's brain. There is no universally agreed on treatment for it, but *melodic intonation therapy* (MIT) has been shown to be effective; patients treated with MIT can overcome difficulties in speech production more quickly than controls that did not receive this therapy.

Plenty of explanations have been proposed as to why MIT achieves the desired effects in aphasic patients, but the whole body of literature agrees on the following, central tenets: Most of language production shows a clear lateralisation to the left hemisphere, whereas homologous areas in the right hemisphere are thought to be more involved in pitch processing and other spectral aspects of acoustic input. Therefore, a severe lesion to the left hemisphere can cause nonfluent aphasia, which inhibits speech production. In this context, MIT supposedly brings about brain reorganisation by recruiting right-hemispheric homologue areas to take over language production that had hitherto taken place in the left hemisphere.

MIT has been extensively tested with speakers of many languages, but, surprisingly, not with native speakers of a tone language. In a tone language, pitch is lexicalised, that is, it contributes to the lexical meaning of a word. These so-called lexical tones occur in languages like Thai, Shan (Tai-Kadai), Vietnamese and Mandarin Chinese. The number of tones varies across the languages, with Thai and a variant of Shan having 5 different tones, for example, whereas Cantonese has 9 tones[1]. Regarding lexical tones, it is of genuine interest to determine if their processing shows lateralisation effects. Two different scenarios are possible: 1) Pitch is processed in the same way as in speakers of English, predominantly in the right hemisphere, and there should consequently be more activation in the right hemisphere. 2) Within speakers of a tone language, pitch processing is largely shifted to the left hemisphere because pitch is important at more fundamental levels of speech production. By "more fundamental" I mean that in Western languages, pitch is only of interest at a suprasegmental level, e.g. to indicate that a whole sentence is meant to be a question. On the other hand, in tone languages, pitch is important at the level of individual segments, because it contributes to the meaning of words.

[1] I am aware that from a phonological perspective, the Hong Kong variety of Cantonese only really has 6 tones, but is still described as having 9 tones for historical reasons.

As we will see in Chapter 3, both scenarios were rejected in favour of a model that allows pitch processing in both hemispheres, depending on whether pitch is presented in a linguistic context or not. Thus, whereas English nonfluent aphasics (especially those with unilateral damage to the left hemisphere) are definitely capable of producing and perceiving pitch – and will profit from the intonation that is part of MIT, it is not straightforward how Chinese patients suffering from the same kind of aphasia would react to MIT.

The remainder of this paper is structured as follows. Chapter 2 gives a proper introduction to MIT. Chapter 3 details how lexical tones are processed and how aphasia in speakers of tone languages affects tone production and perception. To my knowledge, MIT has never been administered to aphasic speakers of a tone language in a research context. Therefore, Chapter 4 puts forward the design of an experiment that would investigate the merits of MIT in a tone language context.

2 Melodic Intonation Therapy

Since its inception in the seventies (introduced by Albert et al., 1973, see Yamadori et al., 1977 for an early treatise), melodic intonation therapy (MIT) was known to facilitate recovery from nonfluent aphasia. Yet, for over thirty years, there were no clear-cut instructions and protocols – which meant that no two sessions were alike. Some interpretations of the protocol would even exclude musically untrained therapists from administering MIT treatment, because sessions should be conducted in a specific key or involve a piano. In order to alleviate this problem, Norton et al. (2009) review the original work on MIT and "aim to simplify the process so any therapist can administer it" (ibid.). It is this revised version of MIT that is presented here.

The general procedure is the following: the therapist presents short phrases to the patient, intoning each syllable on either a higher pitch or lower pitch. Stressed syllables are sung on a higher note, and vice versa. Both pitches should be in a comfortable range for the patient. Usually, there is a minor 3rd between them and, as a rule of thumb, middle C (C4) and the A below it work well for many patients. Figure 1 illustrates phrase intonation on the two pitches that starts out with simple and short phrases on the elementary level. As the therapy progresses, longer phrases are presented to the patient, and the therapist will continuously provide less support. The second important element of MIT is hand tapping: while intoning phrases, the syllables are tapped with the patient's left hand – to activate right-hemispheric regions of the brain. Finally, MIT is an intense therapy, with at least 5 sessions a week, the sessions lasting

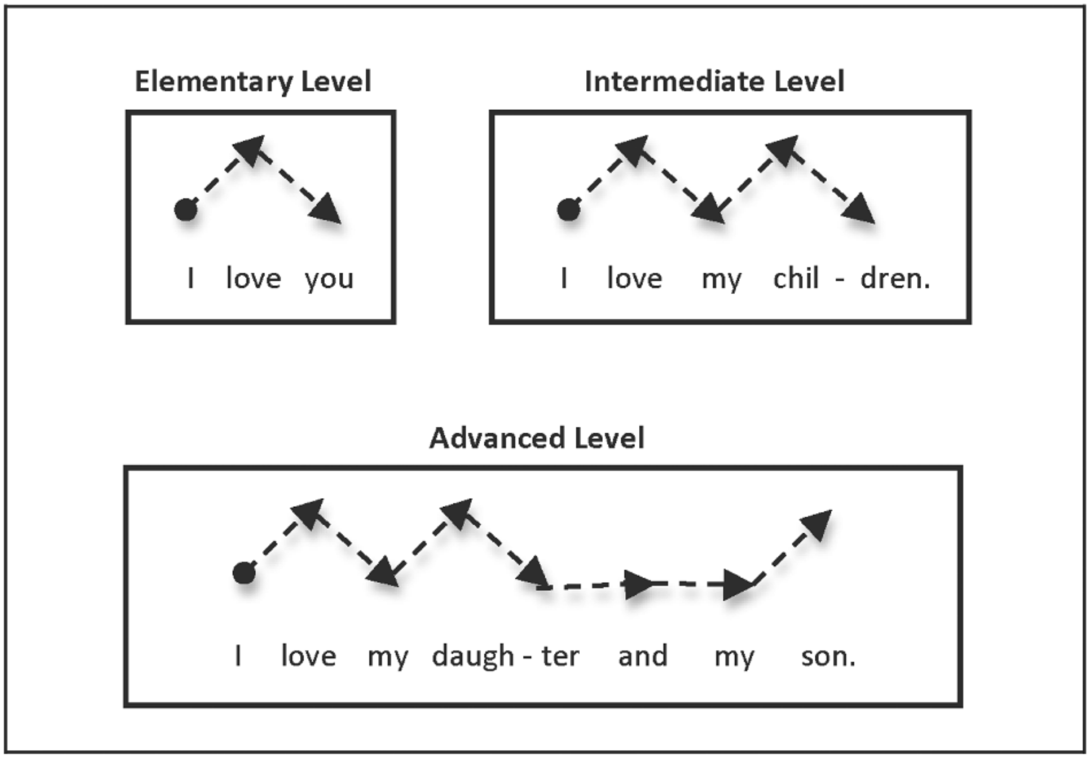

Figure 1: Intoning phrases of varying length, depending on the level of therapy. Stressed syllables are sung on a higher pitch and vice versa (Norton et al., 2009).

1.5 hours. To sum up, the key features of MIT are 1) phrase intonation, 2) hand tapping and 3) intensity.

Opinions differ on which of the aforementioned features is most important for recovery and how reorganisation across hemispheres comes about. Racette et al. (2006) found that neither intoning phrases nor hand tapping is driving this change. Rather, they claim that singing in *unison* with the therapist is the main therapeutic effect: "[what] seems to be critical is to be able to imitate in synchrony with an auditory model". But it should be noted that even though all of their patients had unilateral lesions in the left hemisphere and were diagnosed with nonfluent aphasia, their experiments did not follow the procedure outlined for MIT at all – which makes a comparison to work on MIT very difficult. Work that directly compares MIT to other methods of treatment was done by Schlaug et al. (2008). To get a clear picture of the contribution of MIT, they proposed a control treatment (Speech Repetition Therapy, SRT) that was carefully designed to implement the same procedure as MIT, but leaving away its alleged main features:

intonation and hand tapping. They observed greater improvement in language performance for the patient that had received MIT therapy, compared to a patient treated with SRT. Thus, contrary to the findings of Racette et al. (2006), intonation and hand tapping still appear to be critical. Also, they note that there are "two routes to recovery": For patients with small lesions in the left hemisphere, it is conceivable that other parts of the left hemisphere take over linguistic functions – whereas large lesions in the left hemisphere can only be overcome by activating right-hemispheric regions.

Although MIT was known to have beneficial effects, it was still unclear what cortical changes patients' brains would undergo while receiving MIT therapy. To shed light on this question, Schlaug et al. (2009) investigated the effect of MIT again, this time using diffusion tensor imaging (DTI) to capture changes in fiber connections. The Broca and Wernicke area of the left hemisphere are connected via a major fiber tract, called the arctuate fasciculus (AF).[2] In healthy populations, the AF is very elaborate in the left hemisphere, but underdeveloped in the right hemisphere. Against this background, they found that, after intensive sessions of MIT, the number and volume of fibers in the AF of the right hemisphere increased significantly. This change was put forward as an explanation for the effect of MIT, caused by intonation, hand tapping and, crucially, the intensity of the therapy (75 to 80 sessions in a few weeks). More recently, Wan et al. (2014) confirmed those findings in larger groups of patients and controls, reporting in a more general manner that MIT therapy causes cytoarchitectural changes in the right hemisphere. Specifically, they identified white matter reductions in the inferior frontal gyrus, the posterior superior temporal gyrus and the posterior cingulum – all in the vicinity of the AF.

To conclude this chapter, MIT is still the most effective known treatment for nonfluent aphasia and leads to better performance in speech production earlier on. It is worth noting, however, that not all patients diagnosed with a form of aphasia will benefit equally from MIT. The "ideal" patient undergoing MIT has severe unilateral lesions in the left hemisphere after stroke or trauma and an intact right hemisphere. They are diagnosed with moderate to severe nonfluent Broca's aphasia, still have good comprehension skills and do not have severe amusia or apraxia. Patients with more complex lesions, fluent (Wernicke) or global aphasia will not benefit from MIT. Interestingly, the native language of patients has never been a concern in all work on MIT – and it therefore remains unclear how speakers of a tone language would respond to the therapy. Chapter 3 will head in this direction by explaining the neural correlates of lexical tones.

[2]Malfunction in the arctuate fasciculus is said to cause a further type of language disorder, aptly named *conduction aphasia*.

3 Processing of lexical tones and aphasia

MIT crucially depends on the fact that patients are still able to sing phrases. They are able to do so presumably because utterances with linguistic content and sung lyrics share common networks at lower levels, but are processed by distinct, homologous areas in different hemispheres (see Chapter 14 by Patel in Arbib, 2013 for a discussion). This is a well-established fact and thoroughly tested, but only for speakers of languages that do not have tones, mostly English. For tone languages, the picture might be very different, the rationale for this assumption being as follows. If speakers of Chinese (or any other tone language, for that matter) are diagnosed with aphasia, they will have difficulties in speech production and perception. And since tones are a part of utterances in the same way as vowels and consonants are minimal units in Western languages, one could hypothesise that tone language aphasia *entails* damage to cortical areas that process lexical tone. If pitch processing was indeed affected in ways very different from non-tonal languages, MIT therapy could not be expected to work in this setting. The objective of this chapter then, is to identify the hemisphere (and the specific region, if possible) where pitch processing is taking place in tone languages. Secondly, to clarify to what extent patients speaking a tone language that are classified as suffering from aphasia can can still perceive and produce the tones of their language.

Even though for Gandour and Dardarananda (1983), at the time of writing, methods to capture brain structure and measure activity were crude at best, their work is an early description of unilateral brain damage in Thai. In their study, patients with unilateral left-hemispheric lesions were significantly outperformed by others with unilateral damage to the right hemisphere in a tone identification task[3]. Since they had to rely on behavioural data for the most part, this preliminary finding was later backed up by Gandour et al. (1992), this time with a more thorough investigation of brain structure. Both studies claim that, since lesions in the left hemisphere were more devastating to tone identification, tone processing is biased towards the left hemisphere. In between these two studies, Gandour et al. (1988) published a comprehensive essay that presented evidence from experiments covering both production and perception of tone in aphasic patients. The group of patients and controls was still small, there were only one or two patients with a specific clinical picture, and few healthy controls. They report that unilateral damage to the left hemisphere did not affect tone production at all, since the tones produced by those patients were indistinguishable from tones produced by healthy speakers. But unilateral left-hemispheric damage led to lower performance on tone perception. The very opposite was

[3]For the sake of completeness, there were a whole set of aphasic conditions in this study: Broca's aphasia, conduction aphasia and a disorder they call "transcortical motor aphasia".

true for patients with unilateral right-hemispheric damage, who did not display a drop in perception performance , and were only slightly less accurate at producing tones (around 5 percent difference). At this point, two important observations can be made: First, it is clear that "perception of tone is lateralised to the left hemisphere" (ibid.) and second, that tone production appears to be resistant to unilateral damage, regardless of the damaged hemisphere.

It later became clear that pitch processing might heavily depend on the context in which information about pitch is presented. Indeed, the major finding of Gandour et al. (2000) "is that the presence or absence of significant activation in the vicinity of Broca's area (BA 44) for Thai listeners varies depending on whether pitch patterns are presented in a linguistic or nonlinguistic context, respectively". In addition, they observed that general pitch processing is biased towards the right hemisphere, while pitch in a linguistic context is lateralised to the right hemisphere. They did not extend this description to speakers of other languages, which was made up for in Gandour et al. (2003). In this work, English speakers were subjected to Chinese tones and their brain activation showed a clear bias towards the right hemisphere, presumably because their processing of the tones was utterly non-linguistic. These findings were somewhat challenged by Jongman et al. (2006) who also reported that native speakers of Mandarin Chinese perceive tones in a linguistic context with a strong bias towards the left hemisphere, but English hearers had no preference whatsoever. Nevertheless, all publications mentioned so far gravitate towards the same insight: tone or pitch, be it in a linguistic context or not, is post-processed in the right hemisphere, then further analysed in the left hemisphere, depending on whether the information is classified as linguistically relevant or not (see Li et al., 2010 for a recent summary of this line of thought).

Before moving on, I would like to point out one additional difficulty: Since the seminal work by Goodglass and Kaplan (1983), patients have always been diagnosed with a form of aphasia with the help of the *Boston Diagnostic Aphasia Examination* (BDAE). This includes all experiments with MIT presented in Chapter 2, and many of the experiments with tone and aphasia. Yet, this standardised test builds upon language processing as found in English, and it might not be able to reliably identify tone language aphasia. There are many adaptions of the BDAE for specific languages, e.g. Finnish, and even Cantonese (Yiu, 1992). It is not obvious why the standard version of an aphasia examination should be chosen over one that is specifically adapted to the target language. Potential test subjects should therefore be singled out with the help of a tailor-made examination – which brings us to experiment design.

4 Experiment Design

This chapter is an attempt to devise an experiment that, as far as I know, has not been put into practice until now. That is, an investigation of how aphasic patients speaking a tone language would react to treatment with MIT, or rather, of course, if such a treatment would be beneficial for this specific group. I will first describe the patient groups and the method before hazarding guesses as to what the outcomes might be and why.

4.1 Test subjects

In order to be eligible for the study, patients should ideally

- be speakers of a tone language (Mandarin, Cantonese, Thai, Shan, Vietnamese, Burmese and so on). They should either be monolingual and if bilingual, the second language should ideally also be a tonal language
- have suffered from stroke, with unilateral lesions in the left hemisphere. Also, the post-stroke period should be similar, not in the first months after stroke, where the patients' condition is usually regarded as unstable. As a hard limit, there should not be patients that experienced a stroke within the last two months
- be tested with a language-specific version of BDAE, and diagnosed with nonfluent, moderate to severe Broca's aphasia. Other language-related disorders are equally interesting, but MIT specifically targets nonfluent aphasia
- have the same sex, be of similar age, and not suffer from any other neuropathological conditions. In particular, patients should not suffer from apraxia or amusia
- have received a similar amount of musical training. Intensive musical training before a critical age is known to alter brain regions primarily concerned with pitch processing

There are two different groups of control individuals that would be interesting. Controls could either be

- speakers of a tone language without aphasia. Healthy speakers of a tone language are necessary if speech production performance of aphasics should be measured against a baseline

- speakers of a language without lexical tones with the same kind of aphasia. This control group would allow to infer whether MIT is more beneficial to speakers of a certain group of languages

4.2 Procedure

In the main phase of the experiments, half of the patients and half of the controls would receive intensive MIT treatment, the other halves would undergo intensive SRT. The main difference between those therapies, as explained in Chapter 2, is that SRT explicitly bans intonation and tapping with the left hand. Patients are randomly assigned to either therapy. Each test subject will meet with a therapist 5 days a week, for at least 80 sessions in total. It is up to the therapist to decide when to move on to a higher level of MIT or SRT, but all patients should eventually reach the "advanced" level, while the number of sessions needed should be kept track of. Visual cues must be presented by the therapist for all phrases. It should go without saying that the therapist herself should of course be a native speaker of the same language as the patient, because speaking or intoning in unison seems to be a critical feature of the treatments. All sessions should be recorded and transcribed, with a focus on error analysis, especially with regard to tone production.

4.3 Measurement methods

First of all, the investigators should measure the percentage of correct information units (CIU, see Oelschlaeger and Thorne, 1999 for an exemplary application of CIU to conversation with aphasics), i.e. correct words or notes. This should result in an intuition about the progress of test subjects throughout the therapy sessions. But apart from behavioural changes (speech production performance), MIT is also said to trigger reorganisation of cortical structures. Therefore, DTI should be used to measure the number and volume of fibers in the AF fiber tract before, directly after, and well after the therapy sessions. To put the results into perspective and relate them to the literature, it would also be advisable to use fMRI or a similar method to locate brain activity in some sessions, which would allow observations on lateralisation of certain tasks.

4.4 Anticipating outcomes

It is always a hazard to predict the outcome of experiments that are yet to be done, but I find that well-educated guesses can be made, and that they would not be regarded as outlandish claims.

- If you recall the key features of MIT from Chapter 2: 1) intoning phrases, 2) hand tapping with the left hand and 3) intensity, then, even if tones could not be processed correctly anymore, only the intonation advantage would be impaired. Put another way, even if tone production was out of the question for tone language aphasics, they would likely still profit from the rhythmicity of hand tapping and the intense training.

- MIT rests upon the assumption that there are phrases with more than one syllable, because otherwise syllables of words cannot be intoned on different pitches. Tone languages are heavily isolating languages, and most words only have one single syllable. On top of that, most of the few words that have more than one syllable are loan words. This could have a considerable impact on, if not invalidate, the MIT method.

- The linguistic processing of tone in native speakers of tone langues takes place in the left hemisphere, but tone production seems unaffected by unilateral brain lesions, regardless of the damaged hesmisphere. This leads me to believe that patients speaking a tone language that are diagnosed with Broca's aphasia and suffered from unilateral brain damage to the left hemisphere are very well capable of producing the tones of their language. A similar situation with English would perhaps be to imagine that English aphasics would only have problems with producing consonants, but vowel production would be preserved.

- Non-linguistic processing of pitch is situated in the right hemisphere (in and around the AF), for speakers of tone languages and non-tonal languages alike. MIT aims to recruit those right-hemispheric structures that are preserved in all ideal patients, because they have unilateral lesions in the left hemisphere. Thus, targeting the right-hemispheric pitch processing regions should work regardless of the speaker of the language.

For the reasons given above, I would predict that MIT is an effective treatment when applied to patients that speak a tone language and that otherwise match the characteristics of the ideal patient envisioned by the creators of MIT. Incidentally, this also confirms my own suspicions about the powerful impact music can have on our lives.

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