Chapter 4

The Contingent Negative Variation: The Cumulative Curve Method Revisited

Daniel Dumalin

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.69310

Abstract

The contingent negative variation (CNV) slow waves were elicited using a modified version of the standard paradigm matching the earlier work of Timsit-Berthier. Three parameters, the A3, A5 and post-imperative negative variation (PINV), are measured on four blocks of three to five trials and plotted into a cumulative curve. Five different types of cumulative curves are identified and used for further analysis of a clinical population. A literature review, applying the four-step approach for developing diagnostic tests in psychiatry by Boutros and colleagues is used to assess the current state of CNV as a clinical tool. Two clinical examples are used to illustrate that the cumulative curve reflects the current state of a mental disorder and that follow-up reflects the (un)favorable evolution. Clinical observations indicate that when taking into account the state of a mental disorder, the CNV has potential as a diagnostic aid and can play an active role in the therapeutic decision process.

Keywords: contingent negative variation, event-related potentials, slow cortical potentials, cumulative curve, post-imperative negative variation

1. Introduction

The earliest slow potentials (SPs) emerged from animal studies in the 1950s. Significant steps in man were only made, starting with Walter [1], when the switch to DC recording, or much longer time constants (TCs) were made, which was previously more common in animal work.

Since then, a flurry of studies has been published in an attempt to unravel the underlying processes concerned, variously characterized as arousal, activation, attention, priming, expectancy, motivation, etc. What all of the constructs had in common was an attempt to express the level of involvement existing between a subject and his test environment over a given

period of (examination) time. From the 1980s onward, numerous studies on different patient populations were conducted in an effort to use the CNV as a diagnostic aid.

Despite all these efforts, a chasm seems to prevail between research findings and the experience of clinicians using the CNV as a clinical tool.

This is partly due to the fact that SPs offer its own range of artifactual problems and special technical considerations, such as the use of long time constants (TCs) and the difficulty to elicit reliable responses [2].

Another element that plays a role is addressed by the proposed four-step approach for developing diagnostic tests in psychiatry by Boutros et al. [3]. Most laboratory tests in psychiatry, such as the CNV, tend not to be developed into diagnostic tools. This can only lead to the above-mentioned disappointment and premature abandonment by early adopters or not even implementing a test by most practitioners.

For the clinician, it is important to know what the current status is of a test that shows promising results and see if progress is being made to develop the test into a diagnostic tool. A survey of literature (meta-analysis) should apply the four-step approach not only for clinicians, but also for researchers. Researchers should take count of the need for (simple and low cost) diagnostic tools for psychiatry. They also need to have a clear idea what the current status is of their research tool before progressing further. Is more evidence needed or are the requirements met to proceed to the next level?

The CNV was adopted in clinical practice in Belgium, thanks to the extensive work of Timsit-Berthier and some Belgium companies at the time that developed the equipment for clinical use. However, the clinical utility of the CNV is at present unknown and will be explored in this chapter.

From the above, it seems useful that there should be more interaction between the researcher and clinician, not only from the researcher to the clinician, but also the other way around. Clinicians have the advantage that in most cases they will adhere to a standardized procedure and will apply it for many more disorders than already explored in research. This could provide valuable feedback to researchers where they can best focus their attention first.

Clinicians also have a closer relationship with the test and their patients. They also will do repeated test. This has the potential for interesting observations that can lead to new discoveries that can benefit further development. This potential will be illustrated in this chapter with two clinical examples.

2. Methodology

2.1. Method

2.1.1. Stimuli and procedures

Each subject is presented with a series of paired signals of which the first S1 (warning signal) is a sound of 1 kHz with a duration of 0.5 s. The second sound S2 (imperative signal) is a continuous sound of 750 Hz with a duration of 5 s, which is delivered 1.5 s after S1. Both sounds are delivered through a loudspeaker (open field). The subject is instructed to keep the eyes closed and press a

button (motor response (MR)) to stop the S2 sound at the point that it is clear for the subject that this is the target.

The signals are presented in series of three to five pairs and averaged in real time, four series in total. The duration of each trial is 8 s, with a prestimulus period of 1 s and post-S2 duration of 6 s. An intertrial randomized interval is used between 10 and 11.5 s (**Figure 1**).

Data from 20 EEG scalp electrodes placed according to the International 10–20 System of Electrode Placement with four artefact electrodes (one vertical and two horizontal eye movements, one EMG/ECG) are recorded with one ground electrode and two reference electrodes. Recording electrodes are referenced to linked ear electrodes and processed through analogue EEG amplifiers with a filter band-pass of 0.01–30 Hz with a total acquisition time of 8 s and digitalized with a sampling rate of 256 Hz.

A reject limit is set for each individual subject. This lets you automatically reject a transient high voltage pattern, such as eye-blink and eye-movement artifacts. The appropriate reject level is determined from monitoring the peak values of the first series of three to five pairs, which is discarded. The reject limit is usually set 10 μV higher than the maximum observed peak value. In most cases, this will be about 50 μV. On each trial, the reject limit is compared against the acquired signal amplitude in each channel. If 10 or more points in the input signal have an absolute amplitude value over the reject limit, the trial is rejected.

2.1.2. Methodology background

The Contingent Negative Variation (CNV) slow waves were elicited using a modified version of the standard paradigm of Timsit-Berthier, more closely matching in some respects the author's earlier work [4, 5] rather than the procedure described in her latest publication [6]. However, current method also deviates from Timsit-Berthier's procedures.

Current procedure aims to study the development of the CNV with the focus on the late components of the CNV.

The CNV reaches the maximum amplitude in normal adults in about 30 trials, although it can be fully developed in five to eight trials [7]. The assessment of the temporal evolution is done by

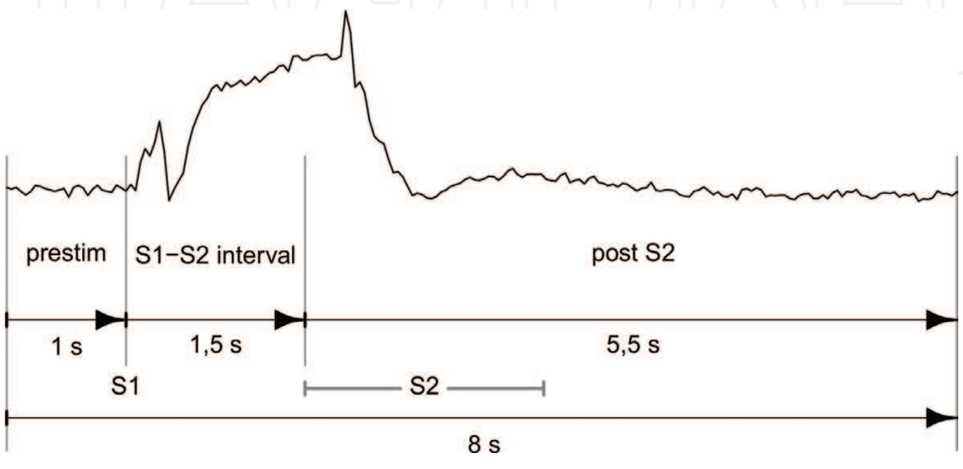

Figure 1. CNV cycle.

applying the cumulative curve method presented by Timsit-Berthier at EPIC IV in 1976 [5] and was never picked up again in later publications. Here we deviate from the presented procedure taking into account the number of trials at which the maximum CNV amplitude is reached. This limits the number of trials to 30 instead of 76, and the number averaged segments from 6 to 4.

The use of a constant-foreperiod reaction-time (S1-S2-MR) procedure is used to optimize the development of the CNV [7].

The S1–S2 time interval of 1.5 s is based on the earlier work of Timsit-Berthier in order to separate the late from the early component of the CNV. With a time interval of 1 s, as used in later publications, the early and late CNV components overlap.

2.2. Analysis

2.2.1. Parameters

2.2.1.1. A3, A5 and PINV

Three different parameters were measured on the CNV curve (**Figure 2**). First, the negative average amplitude of the late CNV was calculated between 1400 and 1600 ms (A3) after the start of S1 at Cz. Then, the positive average amplitude of the post-S2 amplitude was measured between 900 and 1100 ms (A5) after the start of S2 relative to average amplitude of the late CNV at Cz. Next, the difference between A5 and A3 was calculated. The difference is an expression of the post-imperative negative variation (PINV = A5 − A3).

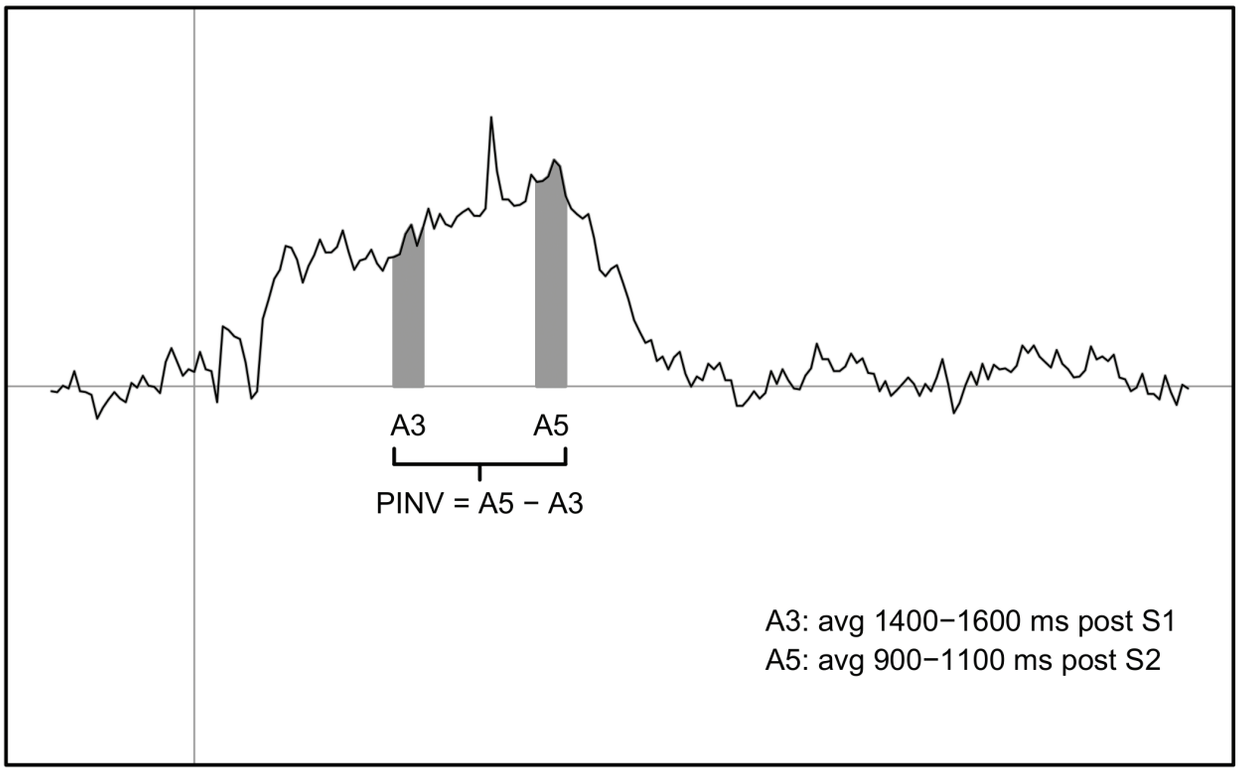

Figure 2. CNV parameters.

These parameters are recorded for each of the four series of averaged trials.

2.2.1.2. Cumulative curve

Two separate amplitude segments are mapped in a cumulative histogram, with negative values above the *x*-axis. On each of the four sequential averages, we note the amplitude of A3 and PINV. On the horizontal axis, the first segment contains four bins of A3 values, followed by the second segment with four bins of PINV values. Each bin of a segment gives the value of the amplitude plus the values of each previous bin.

A normal cumulative curve shows an increasing negativity of A3 and an increasing activity (positivity) of the PINV. Both reach the same absolute value at the end.

From the normal cumulative curve, four major distinguishing types (A–D) can be constructed (**Figure 3**).

1. Type A: the absolute maximum value of A3 is clearly lower than the absolute maximum value of the PINV. The maximum value of the PINV is positive.
2. Type B: the absolute maximum value of the PINV is clearly lower than the absolute maximum value of A3. The maximum value of A3 is negative.
3. Type C: the absolute maximum value of A3 is clearly lower than the absolute maximum value of the PINV. The maximum value of the PINV is negative.
4. Type D: the absolute maximum value of the PINV is clearly lower than the absolute maximum value of A3. The maximum value of the A3 is positive.

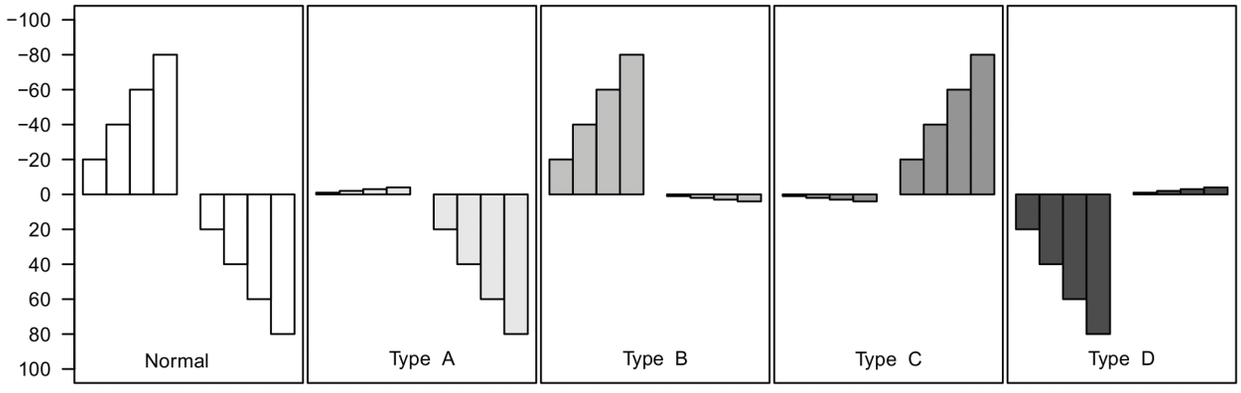

Figure 3. Normal and four abnormal types (A-D) of cumulative curve.

3. Literature

As mentioned before, as clinicians, we like to see research findings developed into clinical (diagnostic) tools. With this in mind, it seems useful to not only contrast current clinical findings of the CNV cumulative curve with research findings, but also assess the current status of

CNV research in regard to its potential as a clinical tool. This was done with a survey of literature and by applying the four-step approach for developing diagnostic tests in psychiatry [3].

3.1. Method

Relevant articles were selected on PubMed, from the National Center of Biotechnology Information (www.pubmed.gov), with the search formula "Contingent Negative Variation" [MAJR] NOT "mismatch negativity" AND (Humans[Mesh]).

This resulted in a total of 674 references which were scored following the proposed four-step model for developing diagnostic tests in psychiatry [3]:

Step 1 demonstrates the presence of a deviant variable in a target group compared to a healthy group and the test-retest reliability. This provides evidence of a consistent abnormality in the target group.

Step 2 demonstrates a significant differential prevalence of a deviant variable between disorders and a healthy group. This demonstrates the potential for clinical utility.

Step 3 demonstrates how promising the findings are for development as a diagnostic test by comparing the target group to proper control groups. It defines the test-performance characteristics and the clinical utility.

Step 4 extends the comparison of the target group versus control groups by using larger groups or by multicenter trials. This step demonstrates the clinical application and sets up standards for clinical use.

This procedure gives us a solid methodology to evaluate literature in prospect of the data analysis of the selected major disorder classes and clinical observations.

A large part of the 674 references were dropped because they were about the Bereitschaftspotential (194) or did not provide sufficient information (97) for classification.

About the same amount of studies were excluded, due to the lack of Healthy Control (71) or Target Group (219). The remaining 93 studies were then classified according to the four-step approach. Next, the number of studied disorders was counted.

3.2. Results

Schizophrenia is the most studied population (19), followed closely by migraine/headache (16). To a lesser extent, Parkinson's disease (7), depression (6) and dementia (5) were researched. The remaining disorders were mostly studied only once and are not considered here (**Table 1**).

The classification on the four-step approach method resulted in 84 studies classified at step 1 and 9 at step 2. In the studies reaching step 2, schizophrenia is the most prevalent disorder used as comparison group, seven out of the nine studies.

3.2.1. Schizophrenia

Studies show that there is a clear presence of a PINV in the schizophrenic patient. Half of the studies found a reduced amplitude of the CNV with an indication of a more frontal distribution.

Disorder	Number
Schizophrenia	19
Migraine/headache	16
Parkinson's disease	7
Depression	6
Dementia	5
Others	52
Total	105

Table 1. Number of disorders as comparison group in selected studies.

3.2.2. Migraine/headache

The migraine patient is characterized with increased amplitude, especially of the early CNV. Several studies also show a perturbed habituation.

Patients with headache rather show a PINV.

3.2.3. Parkinson's disease

In the Parkinson patient, both the early CNV and the late CNV are reduced in amplitude.

Two of the seven studies seem to indicate that there is a correlation between the amplitude and mental functioning.

3.2.4. Depression and dementia

It was not possible to come to any meaningful conclusion due to the use of a wide variety of paradigms, which made a comparison rather senseless.

3.3. Conclusions

From literature survey, it seems promising to use the CNV, at least for schizophrenia, since the studies demonstrate the potential for clinical utility (step 2). To a lesser extent, only two studies, depression also holds promise for clinical utility. However, due to a lack of consistent methodology across studies, further studies are needed to support this.

At present, the comparison of these studies suggests that it seems premature to link a deviant parameter to a single disorder: for example, low CNV amplitude can be found in a schizophrenic as well as a Parkinson patient.

Since there are more parameters (see Section 4.3) that can be measured on the CNV, it seems reasonable to use them in combination in an attempt to differentiate between disorders that show the same change on one parameter.

4. Clinical data analysis

4.1. Subjects

A total of 3757 clinical patients (mean ± SD age = 44.5 ± 15.9) were selected on the following criteria: hospitalized on the psychiatric ward, classified on the DSM-IV-TR and underwent a CNV.

After classifying the patients into the major DSM-IV categories, the groups that had a minimum of 100 individuals were retained.

This resulted in a total of 4196 clinical subjects assigned to six major disorder classes: (1) Substance-Related Disorders, (2) Mental Disorders Due to a General Medical Condition Not Elsewhere Classified, (3) Dissociative Disorders, (4) Schizophrenia and Other Psychotic Disorders, (5) Mood Disorders and (6) Impulse-Control Disorders Not Elsewhere Classified.

Due to the fact that a patient can have multiple DSM-IV numbers assigned, the total number of classified subjects is larger than the population total.

4.2. Results

4.2.1. A3

In all major categories, a minimum of 91% (mean ± SD = 92.2 ± 0.9) of the patients show a normal amplitude of the late CNV. There are also no major differences between the groups for increased or decreased amplitude (**Table 2**).

4.2.2. A5

At least 96% (mean ± SD = 97.5 ± 0.9) of the patients in each major group show a normal amplitude of the post-S2 amplitude. No significant differences were found between the groups for decreased or increased amplitude (**Table 2**).

4.2.3. PINV (A5 − A3)

A normal PINV amplitude was found for a minimum of 88% (mean ± SD = 89.4 ± 1.2) of the patients in each group. Up to 11.6% (mean ± SD = 10.5 ± 1.2) showed an increased amplitude of the PINV, but no significant differences were found between groups (**Table 2**).

4.2.4. Cumulative curve

The type B is the most prevalent with an average of 61.7% (±SD = ±3.0), with no significant differences between groups. Following is the type A with an average of 23.1% (±SD = ±2.9) and type C with an average of 12.2% (±SD = ±2.2). The smallest group is type D with an average of 3% (±SD = ±1.5). Once again, no significant differences between groups were found (**Table 3**).

DSM-IV-TR class		A3			A5			A5-A3		
	N	≤−2SD	≥2SD	NS	≤−2SD	≥2SD	NS	≤−2SD	≥2SD	NS
SRD	1525	0.6	8.2	91.2	1.2	1.7	97.0	8.9	0.4	90.8
MDG	766	0.4	6.7	93.0	0.9	2.3	96.7	11.5	0.4	88.1
DD	155	0.0	9.0	91.0	0.6	1.9	97.4	11.6	0.0	88.4
SPD	111	0.0	8.1	91.9	0.0	0.9	99.1	9.0	0.0	91.0
MD	1497	0.4	6.7	92.9	1.2	1.9	96.9	10.4	0.3	89.4
ICD	142	0.7	6.3	93.0	1.4	0.7	97.9	11.3	0.0	88.7
Average		0.4	7.5	92.2	0.9	1.6	97.5	10.5	0.2	89.4
SD		0.3	1.1	0.9	0.5	0.6	0.9	1.2	0.2	1.2

SRD: Substance-Related Disorders, MDG: Mental Disorders Due to a General Medical Condition Not Elsewhere Classified, DD: Dissociative Disorders, SPD: Schizophrenia and Other Psychotic Disorders, MD: Mood Disorders and ICD: Impulse-Control Disorders Not Elsewhere Classified.

Table 2. Percentage of subjects in each major diagnostic class that shows a significant decreased (≤−2SD), increased (≥2SD) or normal (NS) amplitude for each parameter.

4.3. Conclusions

Data analysis of clinical subjects show that for the six major class disorders studied, the amplitude of the late CNV and the presence or absence of a PINV is unable to differentiate between these classes. The cumulative curve can also not be used to differentiate between the studied major class disorders.

DSM-IV-TR class		Cumulative curve			
	N	Type A	Type B	Type C	Type D
SRD	1404	21.0	63.6	13.1	2.3
MDG	713	24.5	59.6	14.8	1.1
DD	140	26.4	58.6	9.3	5.7
SPD	105	19.0	66.7	11.4	2.9
MD	1394	22.2	60.6	14.3	2.9
ICD	133	25.6	60.9	10.5	3.0
Average		23.1	61.7	12.2	3.0
SD		2.9	3.0	2.2	1.5

SRD: Substance-Related Disorders, MDG: Mental Disorders Due to a General Medical Condition Not Elsewhere Classified, DD: Dissociative Disorders, SPD: Schizophrenia and Other Psychotic Disorders, MD: Mood Disorders and ICD: Impulse-Control Disorders Not Elsewhere Classified.

Table 3. Percentage distribution of the different types of cumulative curves in each major diagnostic class.

These negative results does not necessary mean that we need to abandon the CNV and the cumulative curve. First of all, there are more parameters than the two that have been used in this analysis:

- M1 (early CNV): average value between 500 and 700 ms after S1
- M2 (late CNV): average value of the 200 ms pre-S2 epoch
- M3 (post-sensory positivity): average value between 300 and 500 ms after S2
- M4 (post-motor positivity): average value between 300 and 500 ms after motor response
- M5 (post-sensory positivity): average value between 500 and 700 ms after S2
- M6 (post-motor positivity): average value between 500 and 700 ms after motor response
- SM1 (total surface between M1 and M2): sum of values of all points between 500 ms after S1 and start of S2 relative to the average baseline
- SM2 (total surface between 300 and 800 ms after S2): sum of values of all points between 300 and 800 ms after S2 relative to the average baseline

Apart from using a single parameter, any combination of parameters could be used to improve the differential diagnosis of disorders. This can be extended with a cumulative curve, comparing any pre-S2 averages with one of the post-S2 averages.

Secondly, the author's clinical experience has demonstrated that there is another potential for the CNV and the cumulative curve that has not been considered. Two clinical examples not only help to illustrate this, but also to give some indication why the data analysis was unable to differentiate between disorders.

5. Clinical examples

5.1. Bipolar affective disorder

This patient was examined five times on average every 139.25 days (±SD 40.66 days). The subject was initially examined with an indication of depression. Only on the second hospitalization the patient was sent for examination with the indication for bipolar affective disorder.

Two alternating types of cumulative curves were seen across the five subsequent visits: type A and type B (**Figure 4**). The type A corresponds to the depressive episode and type B matches the manic episode.

When the respective averages were made of the CNV curves for the depressive and manic episodes, classified as such using the cumulative curve (**Figure 5**), differences in amplitude of the late CNV (A3) and PINV (A5-A3) became apparent. Both episodes show decreased amplitude of the late CNV (A3) and also early CNV and is more pronounced in the depressive episode. The manic episode has a value of −9.572 μV for A3 and −0.207 μV for PINV and the depressive episode −3.961 μV for A3 and 8.254 μV for PINV (**Figure 6**).

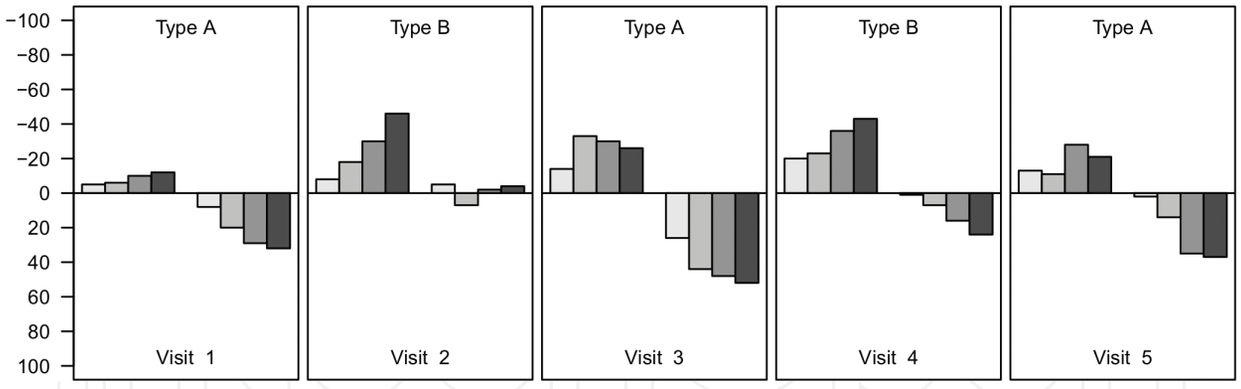

Figure 4. Cumulative curves of a bipolar affective disorder case for each visit.

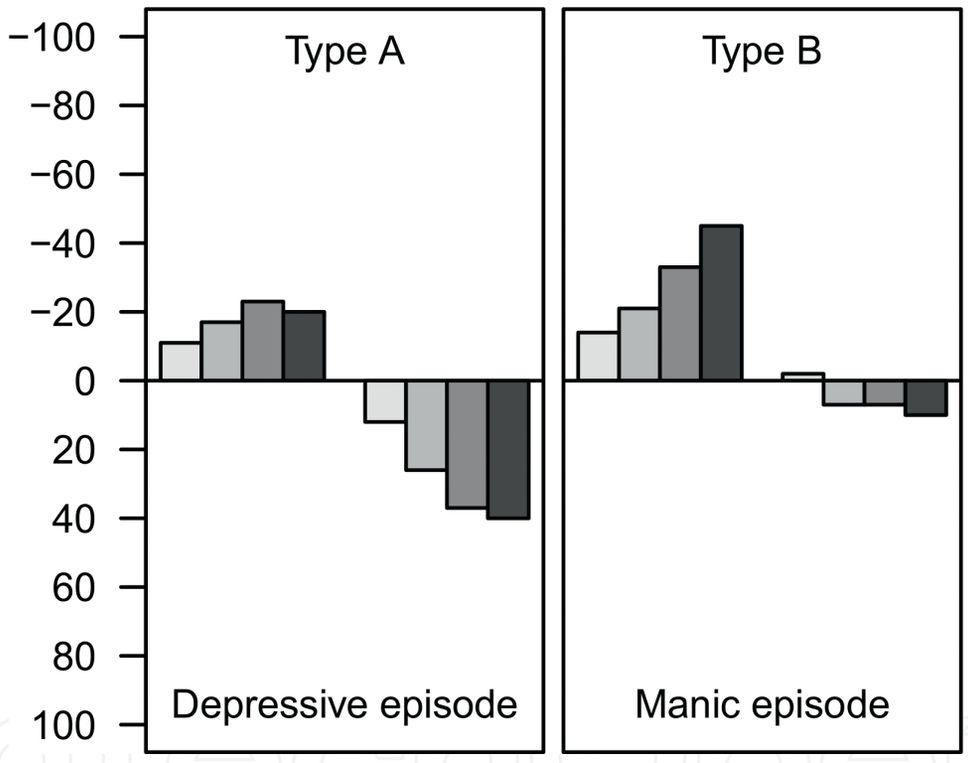

Figure 5. Cumulative curves of the averaged CNV curves of the depressive and manic episodes of a bipolar affective disorder case.

5.2. Stable depression with an episode of decline and recuperation period

This patient was examined 15 times on average every 228.21 days (±SD 75.20 days).

The subject is known with a recurrent major depressive disorder, which was stable as reflected in the cumulative curve of the CNV during eight subsequent visits, on average every 266.00 days (±SD 78.46 days), lasting six years. The stable period was interrupted with one episode of decline following a subsequent number of negative personal dramatic incidences. This was reflected in the CNV by an overall decline of the amplitude and a type C cumulative curve.

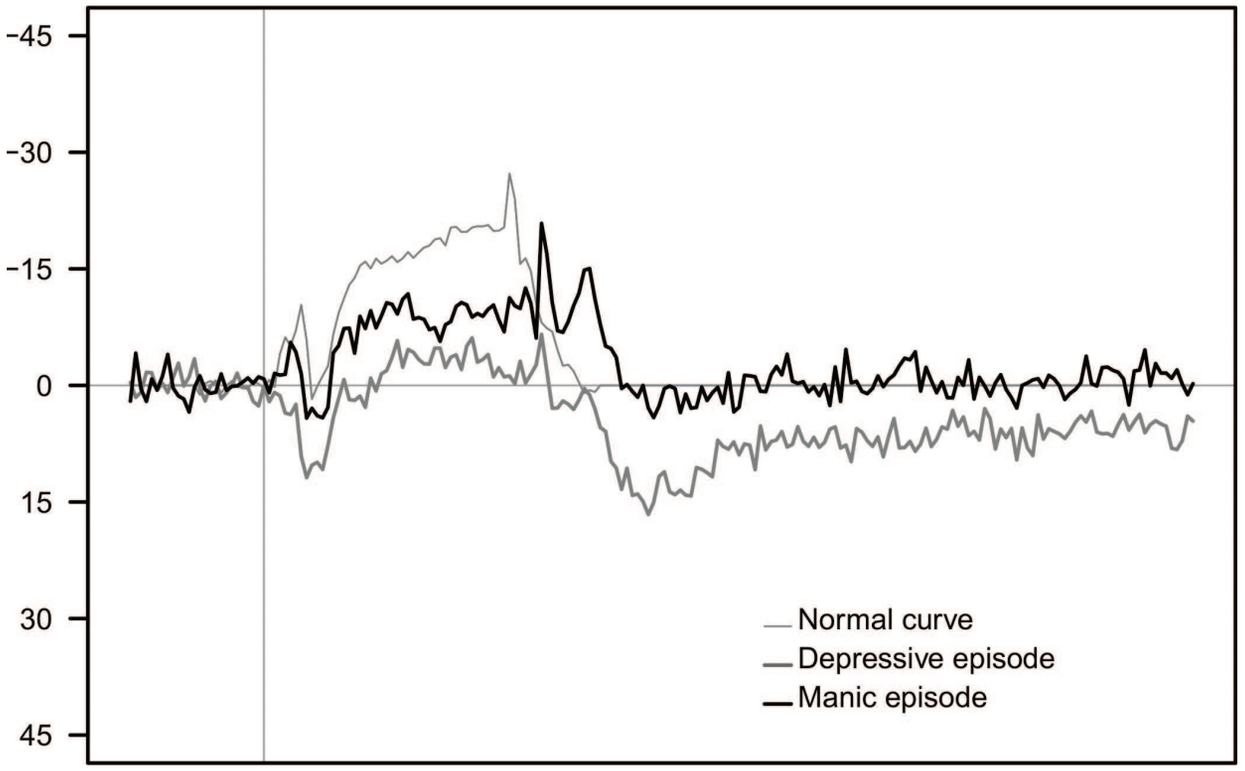

Figure 6. Average curves of the manic and depressive episode of a bipolar affective disorder case.

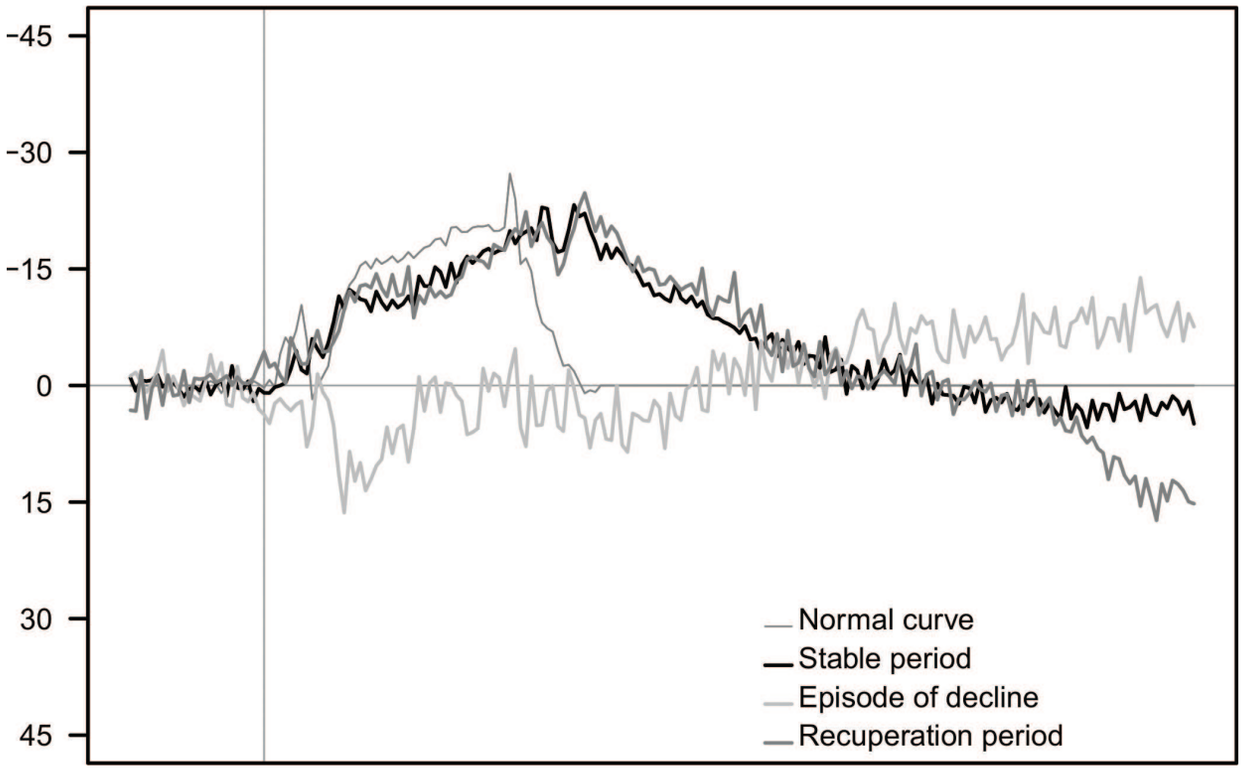

Figure 7. Average curves of the stable and recuperation period of a depressive case together with the curve of the single episode of decline.

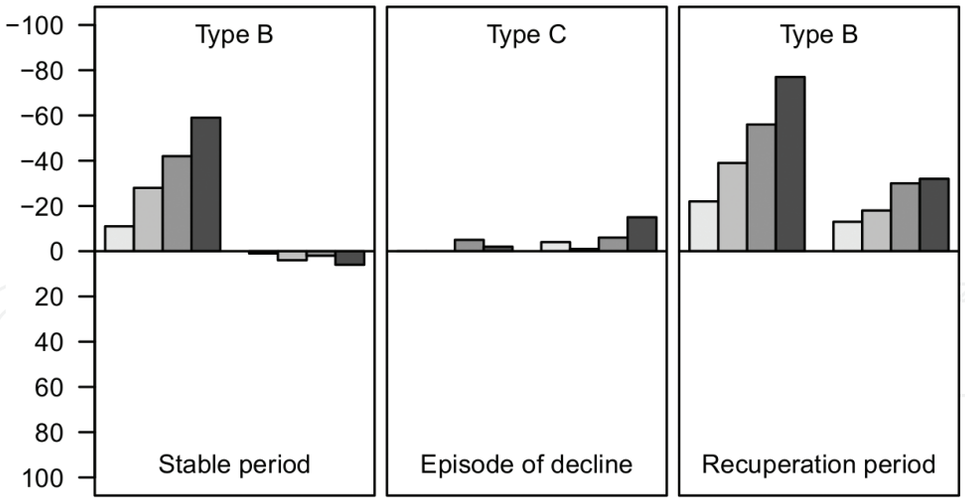

Figure 8. Cumulative curves of a depressive case: stable period, episode of decline and period of recuperation.

The patient recovered and corresponds to the average CNV of six subsequent visits, on average every 198.60 days (±SD 66.65 days). The overall amplitude returned to the previous stable period (**Figure 7**) and a type B cumulative curve was seen again (**Figure 8**).

However, the comparison of the cumulative curves of the recuperation and the stable period shows that the maximum amplitude of the PINV is higher in the last curve. From this, one could either conclude that the patient has not yet fully recovered or will continue to show a lasting impact of this decline (**Figure 8**).

6. Discussion

From literature survey, it seems that the CNV could only be applied for schizophrenics with certainty. Yet, one must remark that this is due to the lack of sufficient studies and the use of a standard paradigm within other patient populations.

From the data analysis of clinical patients, it is clear that the research findings for schizophrenics, the decreased amplitude and the presence of PINV are also found in other disorders. The data analysis also suggests that the CNV cannot be used for differential diagnosis.

Does this really mean that we need to discard the CNV from clinical practice?

To start answering this question, let's return to the two clinical examples.

From the bipolar case, we not only learn that the CNV can at least be used as an aid to diagnose bipolar affective disorder but also might explain why there is a lack of clinical useful findings in CNV research. Within the same patient group, each individual is not in the same state when examined in clinical practice or taking part in a scientific study. This averages out many or all differences one might find if we would take into account the current state of each subject. In mixing both episodes of the bipolar patient, we fail to see the difference in amplitude of the late CNV between the depressive and manic episodes. This mix might also

explain the absence of significant differences between patient groups. This clinical case also demonstrates that the CNV cumulative curve could be used to classify subjects on current state of mental disorder.

The depression case demonstrates the strongest that we can follow the progression of a patient through time. When a patient is worse off, it is reflected in the CNV. Also, any change or no change at all in the state of the patient becomes apparent when comparing previous results. This suggests that the CNV could be used as a follow-up for any possible therapy that is initiated. Ideally, this might be used to increase the effectiveness of a therapy, either tailored to a specific disorder or even the individual patient.

Both cases illustrate that the cumulative curve is the easiest analysis method of the CNV to express the current state and follow the progression of a subject. In general, if the state of a patient continues to worsen, the cumulative curve will change from a type B, through type C and finally to type D in the most unfavorable situation (**Figure 9**). When the patient improves, the cumulative curve will change in the opposite direction. In contrast, the bipolar patient will swing back and forth between the types A and B, bipolar cycle (**Figure 9**), as long as there is no improvement in the patient's condition.

To return to the question, clinical observations seem to support the position that there is no need to abandon the use of the CNV in clinical practice. The CNV cumulative curve shows potential as a diagnostic aid, although limited at this time to bipolar affective disorder. However, the greatest potential might lie in the therapeutic decision process. When a therapy is initiated, its progress can be followed with the cumulative curve. From the proposed model, one can expect that the success of a therapy will be reflected in the cumulative curve. If successful, the natural progression would deviate from its natural course and develop toward a normal cumulative curve. If this can be substantiated, the CNV would have a role as an aid to increase therapeutic effectiveness and reducing treatment cost.

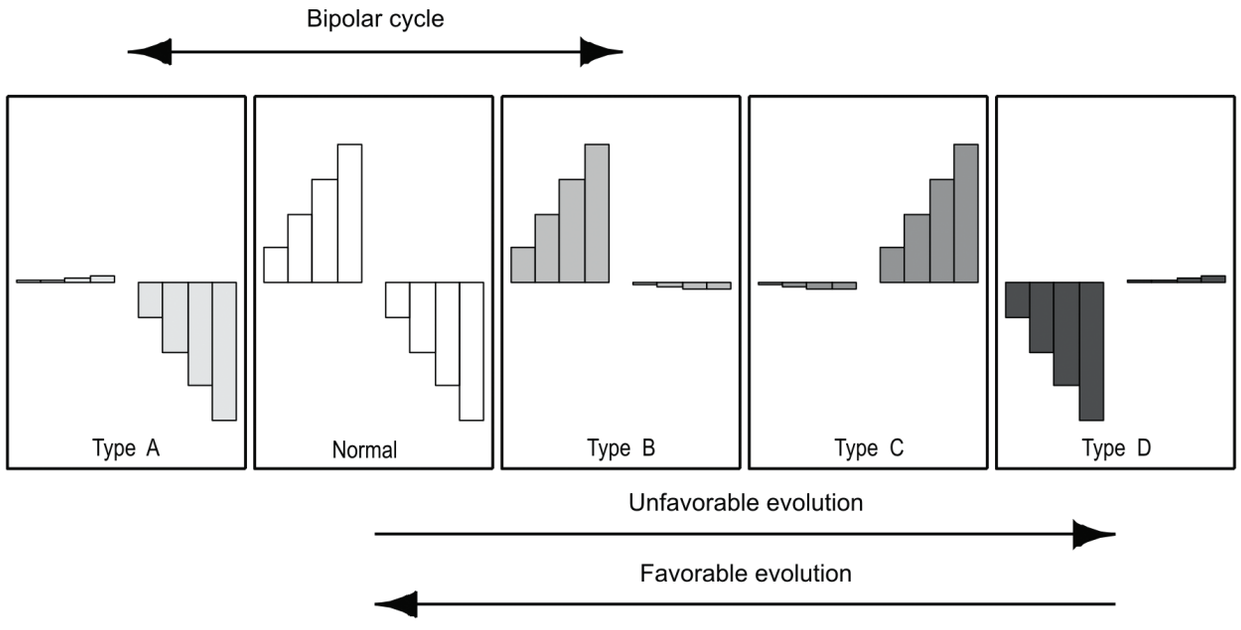

Figure 9. Evolution cycles of the cumulative curve.

It must be clear that more research is needed to confirm these clinical observations. Apart from this, recommendations for further research have been highlighted in this chapter.

First, research should be aware that there is a need for clinical (diagnostic) tools in psychiatry. The four-step approach can be used to assess at what level a test is and ascertain if more research is needed at the current level or the requirements are met to move forward into the next level.

More and better interaction is needed between researchers and clinicians to guide the development process. This close collaboration could result in a full development of a test, from discovery of a consistent abnormality to a standardized clinical (diagnostic) tool. It can also assure that a test will closely meet the needs of the clinician.

We should also not forget previous research. Technology has further developed and offers many more possibilities. This should not blind us from the more 'simple' analysis that has been done in the past. Instead of moving these aside, we should use them to look at them from a new perspective. With current technology, we are no longer restricted to select one or a few parameters, but can also do multiple combinations with a simple push of a button.

Author details

Daniel Dumalin

Address all correspondence to: daniel.dumalin@azsintjan.be

AZ Sint-Jan Brugge-Oostende AV, Ostend, Belgium

References

[1] Walter WG, Cooper R, Aldridge VJ, McCallum WC, Winter AL. Contingent negative variation: An electric sign of sensori-motor association and expectancy in the human brain. Nature. 1964;**203**(4943):380-384. DOI: 10.1038/203380a0

[2] McCallum WC. Human slow potential research: A review. In: McCallum WC, Curry S, editors. Slow Potential Changes in the Human Brain. New York: Plenum Press; 1993. pp. 1-12

[3] Boutros N, Fraenkel L, Feingold A. A four-step approach for developing diagnostic tests in psychiatry: EEG in ADHD as a test case. The Journal of Neuropsychiatry and Clinical Neurosciences. 2005;**17**(4):455-464. DOI: 10.1176/jnp.17.4.455

[4] Timsit-Berthier M, Delaunoy J, Koninckx N, Rousseau J. Slow potential changes in psychiatry. I. Contingent negative variation. Electroencephalography and Clinical Neurophysiology. 1973;**35**(4):355-361. DOI: 10.1016/0013-4694(73)90191-0

[5] Timsit-Berthier M, Delaunoy J, Gerono A. Morphological analyses of the CNV in psychiatry: Comparison of resolution mode and cumulative curve methods. In: Otto D, editor.

Multidisciplinary Perspectives in Event-Related Brain Potential Research: Proceedings of the Fourth International Congress on Event-Related Slow Potentials of the Brain (EPIC IV). Washington: Environmental Protection Agency; 1978. pp. 389-391

[6] Timsit-Berthier M, Gerono A. Manuel d'interprétation des potentiels évoqués endogènes (P300 et VCN). Bruxelles: Éditions Mardaga; 1998. p. 64

[7] Tecce JJ. Contingent negative variation (CNV) and psychological processes in man. Psychological Bulletin. 1972;77(2):73-108. DOI: 10.1037/h0032177