User Guide

Summary

Warnings and Limitations:

The MindPulse test should be interpreted only by qualified healthcare professionals. MindPulse is not intended to be used as a stand-alone diagnostic device for any disease. MindPulse is not designed to identify the presence or absence of a specific clinical diagnosis but rather to screen for cognitive difficulties, which are common symptoms across various diseases and situations. MindPulse is a screening tool designed to assist healthcare professionals in evaluating cognitive status.

Preface to MindPulse

Dear clinical colleagues,

It was within the scope of my clinical practice in neuropsychology that the creation of a new neurocognitive test became a necessity for me. Indeed, while neuroscience has made phenomenal advances and Big Data is changing the face of the technological world, I observed a gap between these developments and the tools used in the clinical practice of psychologists and neuropsychologists. I also wanted to create a tool that would be genuinely cross-cultural, accessible to all, and capable of tracking the cognitive development of a young adolescent as they mature into adulthood. Finally, I wanted a tool that could be used in retesting, with a minimal learning effect, allowing for the assessment of the impact of our therapies and treatments.

MindPulse is the result of 10 years of multidisciplinary research. Three researchers focused on this tool: Professor Bertrand Eynard, a researcher in mathematical physics; Professor Sylvie Granon, a professor of neuroscience at the Institute of Neurosciences Paris-Saclay and head of the "Neurobiology of Decision-Making" team; and myself, a Doctor in Neuroscience and a practicing Clinical Psychologist-Neuropsychologist.

MindPulse is a tool for characterizing fundamental decision-making in a perceptual-motor sense. This characterization, unique to our test, allows us to demonstrate the balance between attentional and executive functions, speed, and accuracy. We discovered that we could also measure a new dimension, the "Reaction to Difficulty." Additionally, our particular method of calculating reaction time, which measures the relaxation after an engagement in action, allows us to better control the inevitable motivational bias encountered in all tools, even if we do not "measure" it directly.

MindPulse is beginning its great clinical adventure. In the coming years, numerous clinical research studies will enrich our understanding of its characterization capabilities. Always keep in mind that you should compare these results with those of the tools you are accustomed to using. I always recommend *never measuring a function with just one tool but rather cross-referencing the data.*

Wishing you much pleasure in using this new tool.

Sandra Suarez

Theoretical Introduction & Tool Construction

1. Theoretical Background of MindPulse

1.1. Executive Functions and Attention

Executive Functions (EF) refer to the set of high-level cognitive processes that enable goal-directed action. These functions allow an individual to adapt to new, conflicting, or complex situations (Diamond et al., 2013; Miller & Cohen, 2003). EF is known for its close links with attentional functions (Gazzaley & Nobre, 2012).

1.2. Fundamental Decision Making

Decision-making (DM) is an adaptive process that enables the selection of an option among several alternatives based on the environment and individual needs. DM relies on numerous circuits and cognitive processes, which can be simplified as shown below (Figure 1). These include a cognitive circuit, an executive control circuit (which encompasses inhibitory control, behavioral flexibility, or working memory), and a circuit for emotional processing that includes an action execution component.

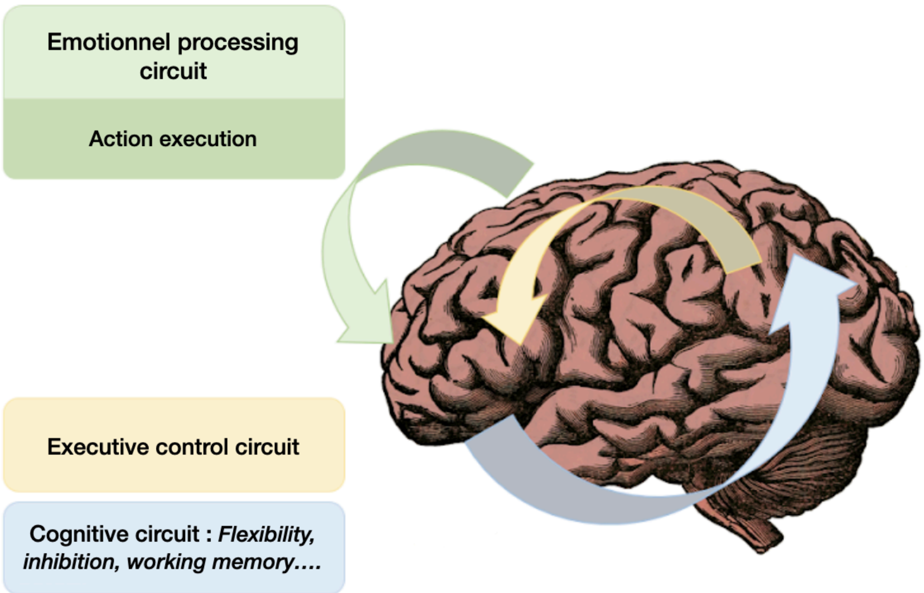


Figure 1 : Circuits underlying decision making

The integrity of these networks and regions is therefore crucial to support the decision-making process.

1.2.1. Classical models of evaluation

In our daily lives, when making a decision, we cannot precisely predict the consequences of our actions, which makes the situation uncertain. Why do we prefer one option over another? Each potential cost and benefit is actually estimated both in the short term and the long term, to weigh our actions based on their consequences. This involves several steps:

- Exploring the different possible options
- Evaluating the value of each option
- Estimating the cost and benefit of each option

> Note: The benefits associated with a decision can correspond to rewards (pleasant events), and the costs can correspond to penalties (unpleasant events).

Following this "experience" and learning, the individual will develop a personal preference that integrates the benefits (rewards) and costs (penalties) resulting from our choices. These preferences are unique to each person and allow us to observe and study individual differences.

Thus, one type of decision-making involves evaluating the available options and is reflected in the selection of an option based on its value coding related to the concept of reward and associated (positive) reinforcement.

For example, traditionally, to study decision-making in humans, tasks such as the Iowa Gambling Task (Bechara et al., 1994) are used.

1.2.2. Perceptivo-motor Model: Go/Nogo task

At a more basic level, perceptual-motor decision-making is the most commonly used measure in the study of decision-making. It involves perceptual or semantic categorization of information, with a motor response modality.

These tasks, also known as "Go/NoGo" tasks, require a motor response (such as a click) to a stimulus corresponding to a specific category (Go trials) and inhibition of the response for stimuli that do not fit the requested category (No-Go trials). The subject must respond if the image matches the requested category (for example, in the diagram on the right, if the sun is yellow) and must withhold their response if the image does not match the requested category (for example, if the sun is blue - see Figure 2).

These basic and sensory decision-making processes are encountered in daily life, whether it's deciding to cross the street when the traffic light is green (acting) or to stay on the sidewalk when it's red (withholding action), or when faced with danger and choosing between "fighting" or "fleeing."

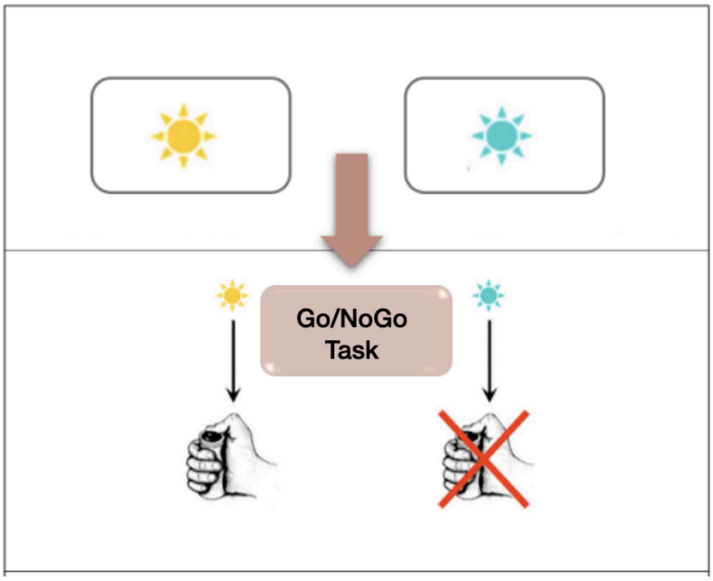


Figure 2 (from Vidal et al., 2020). Illustration of a Go/NoGo task

Therefore, the assessment of decision-making will vary depending on the measures studied, as the processes involved differ between the various tools and methods chosen.

1.3. Interaction between processes

The ability to make appropriate decisions depends on the proper functioning of various structures and networks (Bari & Robbins, 2013 - Figure 3), as well as on the interaction between the different processes involved at each stage.

The dynamic control and adjustment of our behaviors in response to environmental feedback depend on the balance between attention, inhibition, and cognitive abilities.

Studying this process is crucial because ineffective decision-making is a major source of daily difficulties and decreased quality of life for individuals with mental and/or cognitive disorders. Yet, even today, we have limited information about the various factors responsible for defective decision-making depending on the types of disorders or underlying brain functions. Determining the origin of these difficulties seems important both clinically and theoretically to better understand which function is impaired and causing inappropriate decision-making.

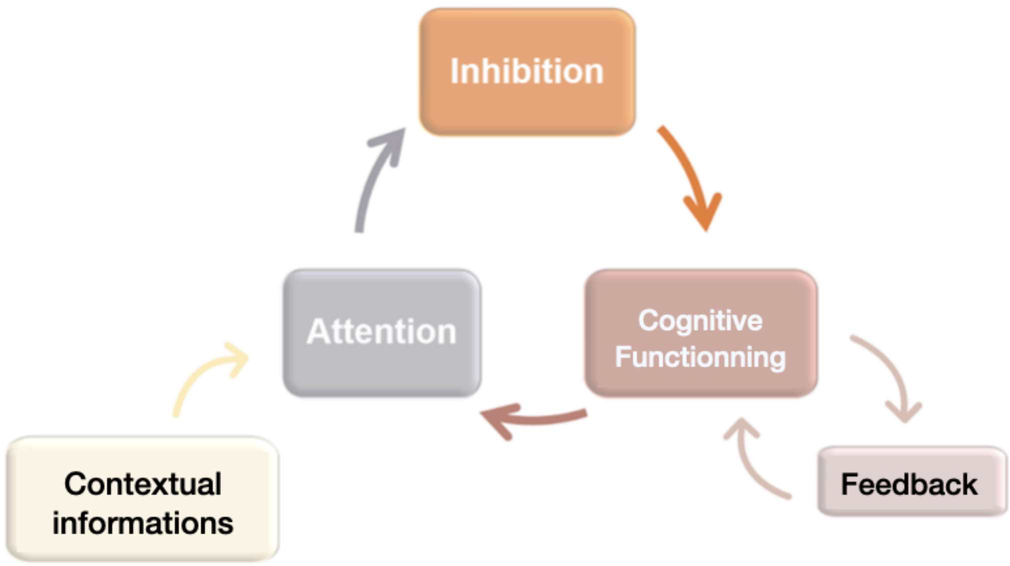


Figure 3. Representation of the hypothetical simplified relationships between different executive functions, adapted from Bari & Robbins, 2013.

Among the subcomponents of decision-making, we will focus more specifically on attentional capacities, which are necessary for directing attentional focus on essential information during decision-making.

1.3.1. Attentional Component

Attention is crucial for optimal cognitive functioning because it directs the processing of relevant information according to our goals. Several models explain attentional functioning, including the model by van Zomeren & Brouwer (1994), which breaks down attentional capacities into two main functions:

- **The selectivity function of attention:** This function allows for the selection of a specific stimulus to process it in depth. It includes focused attention, which enables the selection of a relevant stimulus by inhibiting distractors, and divided attention, which allows performing two tasks simultaneously.
- **The intensity function of attention:** This is the general state of activation that allows for processing and responding to stimulation with varying levels of efficiency. This function includes phasic alertness, which mobilizes resources quickly in response to a signal, and sustained attention, which maintains attentional levels over extended periods. Additionally, there is an attentional supervisory system, a central process that controls and manages attentional resources.

Attention disorders are present in many pathologies and can particularly impact decision-making. Indeed, effective decision-making requires essential attention to focus on relevant information so that our response is continually updated and adapted to the needs of our body and environment (Bari & Robbins, 2013). This adaptation is also possible thanks to another process we are also interested in: inhibition.

1.3.2. Inhibition Component

In a constantly changing environment, the ability to adapt to all types of situations is essential for optimal cognitive functioning. Inhibition plays a key role in this by controlling interference. Consequently, a deficit in inhibition can greatly impact the decision-making process, which in turn affects daily life, leading to various behavioral and psychopathological or psychiatric disorders.

Thus, since decision-making is a sequential process, in clinical and psychometric practice, the final goal observed is the motor execution of the action, which is the motor response.

2. Motor Response : psychomotor slowing

In most cognitive tasks, we measure the behavioral output, which is the execution of the motor act and corresponds to the response time. This response time (RT) reflects the speed of execution between the presentation of the stimulus and the response to the task.

When evaluating decision-making, our decisions are made under time constraints, which can lead to a slowing of the response in order to remain accurate and precise. This slowing down of action speed to respond to a task is often referred to as psychomotor retardation (Roussel & Godefroy, 2019), and when it becomes excessive, it can become problematic. Psychomotor retardation then becomes a pathological state described as a disruption of psychomotor activity and is a common symptom in various pathologies, such as subcortical-frontal disorders, certain cases of depression, anxiety, or as a result of medication, substance abuse, or psychotropic use, affecting subcortical-frontal or more broadly frontal loops (for more details, see the article here: https://itsbrain.mindpulse.net/en/article-adult-norm/).

The presence of psychomotor retardation across multiple diagnoses underscores the importance of determining its origin. Its recurrent nature can obscure its origin, which is both varied and largely undetermined. Indeed, this slowing down can stem from disturbances at different levels, such as perceptual, motor, attentional, and decision-making processes, as proposed in the model by Godefroy et al., (2010) (Figure 4). This confusion regarding the origin of the slowing can increase diagnostic imprecision or errors.

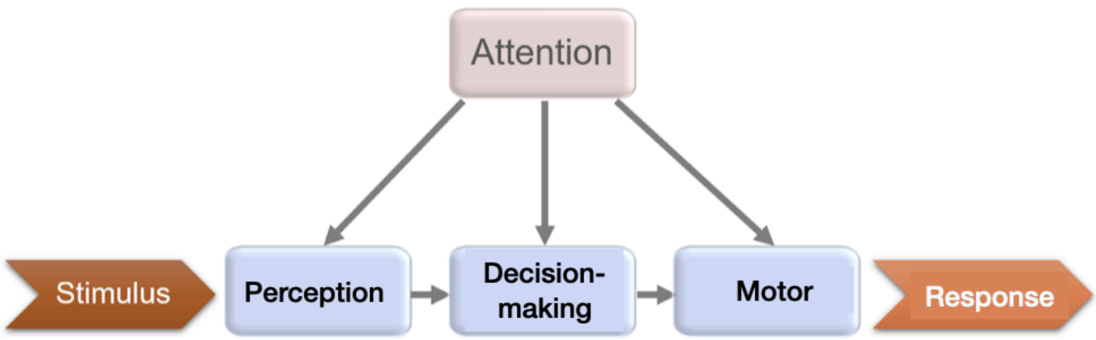


Figure 4. Representation of the simplified processes involved in a simple reaction

time task, presented in the article by Roussel & Godefroy (2019).

It seems important to clarify the measurement concerning the motor response, which remains a major measure in clinical tests. Specifically, being able to measure psychomotor retardation to assess the functionality of an individual's cognitive processes and to discern the precise cause of this slowing in cases of dysfunction remains to be developed.

The significance of measuring decision-making in executive and attentional evaluation has been discussed in more detail on our website: https://itsbrain.mindpulse.net/en/executive-decision/

3. Evolution toward new modelisations: the DDM

3.1. DDM Introduction

Cognitive evaluations of executive functions generally require completing a task quickly or providing as many correct responses as possible within a given time frame. Consequently, these evaluations involve a trade-off between the speed and accuracy of responses. Measures typically address these two parameters as separate components or attempt to quantify the interaction between these aspects. However, this trade-off is influenced by conscious control, where individuals may prioritize either speed or accuracy, as well as by underlying mechanisms that can vary. This pertains to decision-making: the implementation of a choice and the observation of its consequences based on the elements of a given situation. These elements, however, are not independent of each other. For example, a slowing of responses might result from a more cautious decision-making process or from illness-related slowing, which might not be distinguished by conventional methods (Myers et al., 2022).

To better understand cognitive and emotional functions, MindPulse is committed to employing a decision-making measurement methodology that accounts not only for accuracy and speed but also for their interaction. This is precisely what the Decision Diffusion Model (DDM) offers, and its link to these parameters has been validated in numerous studies in cognitive psychology (Myers et al., 2022). The DDM has become a dominant model for rapid decision-making, and some have suggested it should replace mean reaction times and accuracy as default measurement tools in cognitive psychology (Evans & Wagenmakers, 2020). Initially implemented at MindPulse for our research collaborations, our goal is to incorporate this methodology into clinical practice.

The DDM is a model that helps to better understand how an individual makes decisions, such as choosing between two options. It captures the complex relationship between choice and reaction times by decomposing behavioral data into internal cognitive components of the decision-making process (Myers et al., 2022). It produces parameters that integrate both reaction time and accuracy data into a single set of performance indicators (Ratcliff & McKoon, 2008). The DDM assumes that decisions are made through a noisy process that accumulates information over time from a starting point toward one of two response criteria (true/false), along with the individual’s personal speed-accuracy trade-off parameters. The DDM conceptualizes decision-making as a process in which, on each trial, individuals accumulate evidence in favor of one response alternative over another until a sufficient amount of evidence reaches a criterion or threshold, at which point a decision is made and the corresponding response is initiated. The trade-off between speed and accuracy reflects this critical balance point that determines when to stop gathering information and make a decision based on the available data.

3.2. DDM component

3.2.1. Drift

The main components of the DDM include information processing efficiency (the drift rate), which is the speed at which an individual accumulates information toward the correct decision boundary. It is influenced by individual differences in development and states of arousal (Ratcliff & Van Dongen, 2011). For example, the drift rate slows down in depressed subjects (they accumulate the necessary evidence for making decisions more slowly than controls; Pitliya et al., 2022).

3.3. Boundary (B)

Another parameter of interest is the boundary separation, often referred to as "B." Boundary separation is primarily determined by an individual's personal speed-accuracy trade-off parameters or can be influenced by an explicit strategic choice (Huang-Pollock et al., 2020; Ratcliff & McKoon, 2008). Boundary separation can be seen as a reflection of caution in responses, with higher "B" values emphasizing accuracy over speed, and lower "B" values favoring speed over accuracy. The consequence of having a larger "B" value is that the decision-making process becomes slower and more cautious. This occurs because a greater amount of evidence is required before reaching a distant boundary and triggering a response. The advantage of this is higher accuracy, as it becomes less frequent for the decision-making process to erroneously cross the wrong boundary (Lerche et al., 2020).

3.4. Ndt (non decisional time)

The "ndt" (non-decision time) refers to a portion of the response time that is not described by the diffusion model, sometimes interpreted as the speed of evidence encoding before the decision and the post-decisional translation of the choice into a motor response (de Gee et al., 2020), as well as mind-wandering during the decision-making process (Boehm et al., 2021). The starting point of the diffusion process is influenced by the test construction and is interpreted as a bias towards the "go" or "no-go" boundary, and should be set in the middle between the two boundaries for a defect-free test (Boehm et al., 2021). The value of the DDM parameters, providing the best fit to a response distribution, is to help identify the cognitive processes underlying decision-making processes (Voss et al., 2004; Voss & Voss, 2007; 2008).

Atypical decision-making has been associated with a variety of conditions, ranging from depressive and anxiety disorders (Pitliya et al., 2022; Chen, 2022) to borderline personality disorder (Hallquist et al., 2018), as well as Parkinson's disease (Frank et al., 2007; Moustafa et al., 2008) and suicidal tendencies (Brenner et al., 2015; Dombrovski & Hallquist, 2017). Gaining a deeper understanding of the cognitive and neural bases of atypical decision-making in these populations is crucial for improving psychological and pharmacological treatment strategies, as well as ensuring treatment adherence.

3.5. Confidentiality and Data Anonymization

MindPulse (with the data processing protocol described here) has been registered in the data processing register of the Assistance Publique – Hôpitaux de Paris (APHP) (November 2022), validating that its use at APHP complies with GDPR regulations. Therefore, all clinicians at APHP will have permission to use it.

3.5.1. Typical clinical case example

Patients are systematically informed about data processing at the beginning of the test and must provide their consent by checking a box. The clinician must confirm at the end of the test that they have obtained the patient's consent for data processing.

During the MindPulse test, participants' personal data is pseudonymized (name, first name, month, and year of birth are automatically transformed into a unique identifying code according to the SHA256 hashing encryption protocol (high security)). Names and first names are neither recorded nor transferred.

Collected data is transmitted encrypted (RSA protocol with public/private keys) and then decrypted with the key on the It'S Brain server. The It'S Brain server is protected and maintained by XEFI. All computers at It'S Brain are protected by XEFI.

List of transferred data:

- Month and year of birth
- Date of test administration (day, month, year)
- Clinician code
- Time of test administration
- CITE 1997 code (International Classification of Education, cf. UNESCO 1997)
- Gender
- Language

- Lateralization
- MindPulse results: reaction time measurements in milliseconds and types of errors

Any patient who wishes may withdraw their consent for the use of their data for research within one month after the test. To do so, they must contact the investigating clinician, who is the only one able to provide It's Brain with the identifier code to be deleted.

Data retention is for one year. After one year, MindPulse data is strictly ANONYMIZED (by removing the month of birth, date of test administration, and identifier code) and stored on a server hosted by XEFI, compliant with HADS standards (Health Data Hosting, adhering to the recommendations of the High Authority of Health), for potential future research projects.

Thus, only anonymized MindPulse data, as AUTHORISED BY LAW (GDPR), is stored long-term, containing:

- Year of birth
- Age at the time of the test (in months, with an error of +/- 30 days)
- Clinical code indicating the pathology
- Time between the diagnosis of the pathology and the test administration
- Month and year of test administration (day removed)
- Time of test administration
- CITE 1997 code
- Gender
- Language
- MindPulse results: reaction time measurements

3.5.2. Case of Use in a Research Protocol

Before starting the study, participants will be informed about the research protocol and the procedures for handling the collected data. They will need to confirm their consent to participate. Participants will also be informed that they have the right to withdraw their consent and oppose the transfer and processing of their collected data at any time, without justification.

During the MindPulse test, participants' personal data are pseudonymized. Specifically, their name, surname, month, and year of birth are automatically transformed into a unique identifier code using the SHA256 hashing encryption protocol (high security). Therefore, names and surnames are neither recorded nor transferred.

The collected data are transmitted encrypted (RSA protocol with public/private keys) and decrypted with the key on the It's Brain server. The It's Brain server is protected and maintained by XEFI. All computers at It's Brain are protected by XEFI.

List of Transferred Data:

- Month and year of birth
- Day, month, and year of the test
- Clinician code
- Test time
- CITE 1997 code (International Standard Classification of Education, UNESCO 1997)
- Gender
- Language
- Laterality
- MindPulse results = reaction time measures in ms and types of errors

Participants have a one-month period after the test to withdraw their consent for the use of their data for research. To do this, they must contact the investigating clinician, who is the only one able to provide It's Brain with the identifier code to be deleted.

Long-Term Data Storage: At the end of the scientific study, once finalized by the publication of a scientific article, the raw MindPulse data are strictly ANONYMIZED (by removing the month of birth, the day of the test, and the identifier code). The anonymized MindPulse data will contain:

- Year of birth
- Age at the time of testing (in months, with a +/- 30 days error)
- Month and year of testing (day removed)
- Test time
- CITE 1997 code
- Gender

- Language
- MindPulse results = reaction time measures

These anonymized data are stored on a server hosted by XEFI, complying with HADS standards (Health Data Hosting Provider, in accordance with the recommendations of the French National Authority for Health).

For potential future research projects and with the researchers' agreement, these anonymized data may also include a clinical code indicating the pathology and the time between the diagnosis of the pathology and the test.

In conclusion, only ANONYMOUS DATA, AS AUTHORIZED BY LAW (GDPR), will be stored long-term for scientific and technical improvement purposes.

No hospital data (medical data and biological data, etc.) is transmitted to It’s Brain's data storage servers. The MindPulse platform does not allow the transmission of such data; it is NOT used for managing patient data.

In some collaborations (with a collaboration agreement in this case), if data necessary for scientific treatments (data analysis) are worked on jointly by teams, these data remain within the research teams and are not included in It’s Brain's data storage. They are therefore deleted after the research by the It’s Brain research team.

MindPulse Utilisation

1. General Terms and Conditions

MindPulse is a neurocognitive assessment test for evaluating cognitive functions. It may only be used within this context and by authorized clinicians. Any use outside of this framework is strictly prohibited. Any misuse, such as for "cognitive stimulation" purposes, is strictly forbidden and violates the terms of use.

Professionals in Cognition

MindPulse, in its "expert" version, is a professional tool intended for qualified clinicians, including psychologists, physicians, speech therapists, psychomotor therapists, and occupational therapists. The "screening" version (in preparation) will include other professions interested in visual attention issues, such as orthoptists and nurses.

Targeted Disorders

MindPulse is designed to assess and quantify moderate and minor disorders. In cases of severe disorders, difficulties in understanding the dual-task instructions may make the test administration impossible. Incomplete assessments (when one phase of the test could not be administered) cannot be analyzed.

Responsibility for Administration and Testing

The clinician solely decides on the appropriateness of administering MindPulse and is responsible for interpreting the results. All administration is conducted under their clinical responsibility.

Age of Administration

MindPulse is standardized for individuals aged 13 to 80 years. Interpretation of results is not possible outside these age ranges. Standardization for individuals aged 9 years and older is in progress and will soon be available for clinicians.

Suitable Environment

Professionals must have a room suitable for cognitive testing. MindPulse results can be compromised by poor testing conditions (noise, interruptions, disruptive elements, excessive stress, etc.). In the case of remote testing, the clinician retains responsibility for the testing situation and must monitor the test administration through a teleconsultation.

2. Mandatory Material

To use MindPulse, you need:

- A 64-bit computer connected to the internet: A 32-bit operating system is not compatible with MindPulse.
- A recent version of Windows or Macintosh: Versions prior to High Sierra (Mac) or Windows 10 are not compatible with the offline installation of MindPulse. If you have an earlier operating system, MindPulse can still be used in its Online version.
- A high-quality wired mouse (with a cable). Ideally, a "gaming" type mouse is recommended. The use of a touchpad is possible, but please note that the norms were established using a wired mouse. Thus, this change may need to be considered in the interpretation of results. Wireless mice are not recommended because their detection is usually slower, which can distort patient scores. It is important to check the quality of the wired mouse connection in advance and conduct preliminary tests to ensure accurate detection and connection.

3. Testing Conditions

The use of MindPulse relies on several recommended parameters. Checking these parameters is crucial to ensure optimal testing conditions and the reliability of the results obtained.

The participant should be welcomed into a quiet room and seated in front of a computer to fully focus on completing the test. No interruptions should occur in the room during the test.

Noise or visual disturbances (such as lighting issues) should be kept to a minimum. The sound should be turned off.

It is advisable to close as many running applications as possible. If possible, shutting down all running applications is recommended.

The screen's resolution and brightness should be sufficient to ensure proper perception of the stimuli. Strong (but comfortable) lighting is recommended to enhance color contrast. Strong contrast between a white background and gray items might be challenging for individuals sensitive to bright light; in this case, adjust the screen brightness to ensure the participant can clearly distinguish the color of the stimuli (White vs. Gray).

The distance between the participant and the screen should also be checked to ensure that the stimuli can be clearly perceived.

Depending on the participant's level of autonomy, it is preferable to conduct the test alone, without the presence of a third party or a parent in the room. Facial expressions or gestures from another person in the room could lead to attentional distractions that might impact the test performance.

4. Test Duration

The complete MindPulse protocol takes approximately 15 minutes, from the start of the test to its completion. An additional 2 to 5 minutes should be allowed to receive the results in the form of a report for the clinician.

5. MindPulse Online utilization

To avoid the need for software downloads and to simplify the clinician's work, MindPulse has recently developed its MindPulse Online interface. This platform centralizes all information and tools related to the use of MindPulse. Accessing this interface requires registration and an internet connection for each use. It consolidates the patient list, test progress status, the number of available reports, and offers the option to purchase additional reports or training online.

5.1. Registration

The first step to access the MindPulse Online platform is to create your client account. You can create your account at this link:

https://www.mindpulse.online/en/signup

Simply fill out the requested information. You will then receive an activation link via email, which will allow you to access the platform automatically after a few minutes.

5.2. Connection

Once your account is created, you can log in to your Online space using the following link:

https://www.mindpulse.online/en/login

Simply enter your contact email and password. You will then access your personalized space.

MindPulse updates will be automatically performed, so you don't need to do anything.

5.3. New test

To take a MindPulse test, simply click on "Test MindPulse" on the MindPulse Online homepage. This button will allow you to create a new patient by filling out the required fields and will automatically start a new test once the information is entered.

5.4. Clinicien workspace

The clinician space is an interface designed to centralize all the information related to your use of MindPulse. This space has been designed to be as intuitive as possible. You will find several tabs there

5.4.1. Homepage

Once logged into your clinician space, you will automatically land on your homepage. This page provides the main information related to your use of MindPulse (see Figure 5):

- **Remaining Reports**: The number of reports you have left.
- **Recent Reports**: The most recently downloaded reports and their dates.
- **Pending Tests**: Tests awaiting completion (for remote testing) or download.
- **Purchase and Training Buttons**: Buttons to purchase additional reports or to sign up for training sessions.
- **Start a Test**: Buttons to initiate a MindPulse test for a new patient or a previously tested patient (re-test).
- **User Manual**: Access to the MindPulse user manual.
- **Latest News**: The latest updates from MindPulse at the bottom of the page.

The command bar at the top allows you to:

- **Show/Hide Navigation Sidebar**: Toggle the visibility of the navigation sidebar.
- **Contact Us**: Send a message if you have questions or need assistance.
- **Change Language**: Switch the clinician space language between French and English.

- **Account Information**: View your account information by clicking on your name.
- **Logout**: Log out of your account.

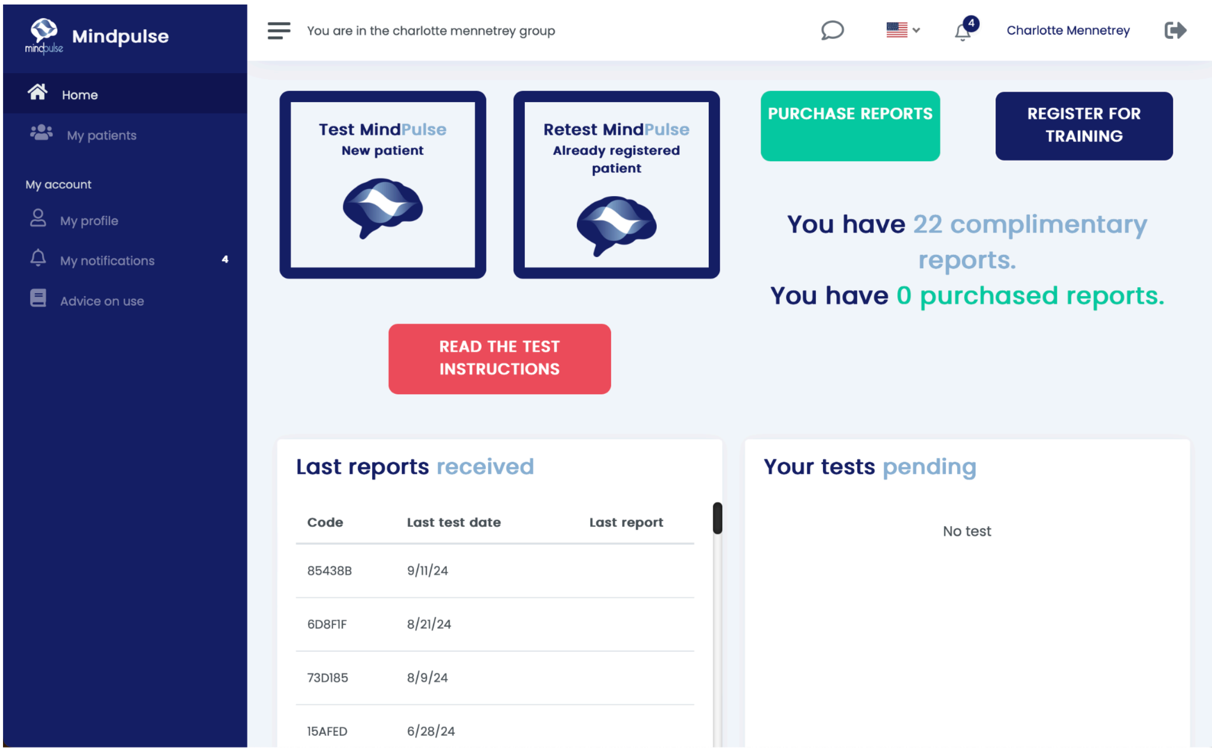


Figure 5. HomePage of MindPulse Online Workspace

5.4.2. My patients

The “My Patients” tab consolidates all information related to the patients you have entered and to whom you have administered the MindPulse test.

- **Encryption**: All information is automatically encrypted, preventing access to your patients' personal details. However, if you need to access this information, you can temporarily “Decrypt” it by clicking the corresponding button. This also allows you to verify the correspondence between your patient's code and their name. You will be prompted to enter your password to decrypt the information (see Figure 6).
- **Downloading Reports**: From this page, you can download MindPulse reports for your patients or re-download them later if necessary. For deferred sending, you can request a report directly from this page with a single click.

- **Editing Patient Information**: You can edit details related to your patients, create new patient records, and export the patient list in CSV or XLS format if you wish to keep a copy on your computer.

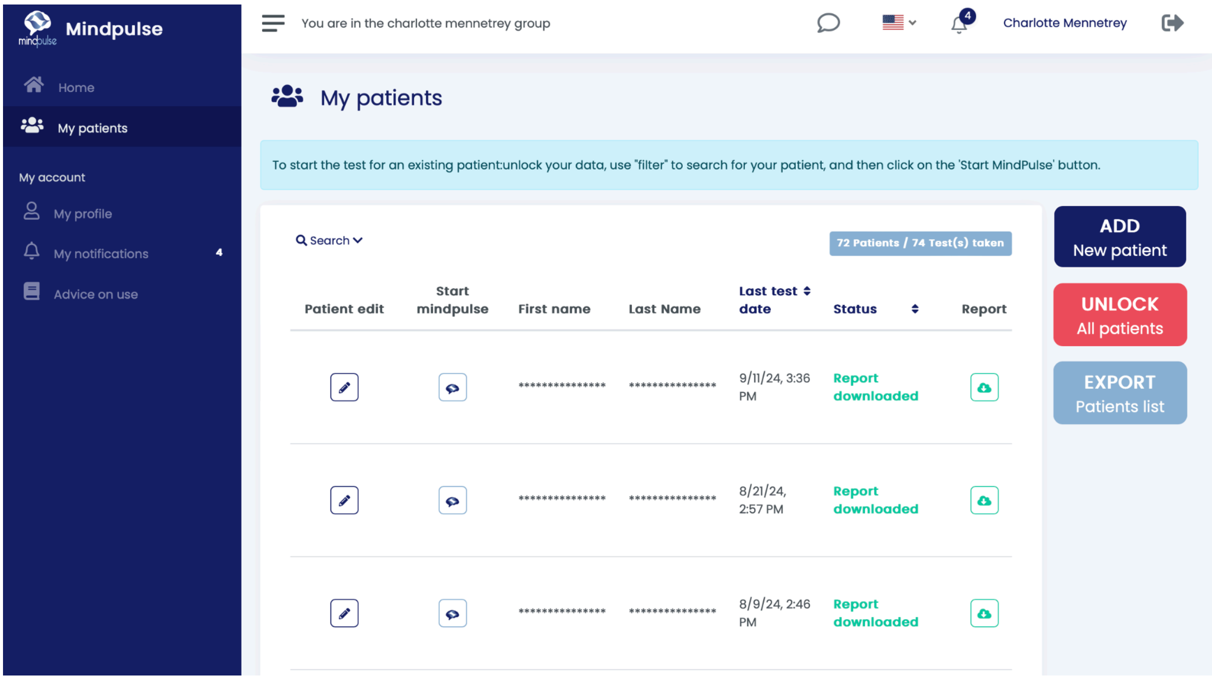


Figure 6. “My Patient” page

5.4.3. My profile

The “My Profile” section allows you to access all information related to your account. Here, you will find your personal and professional details, as well as the activation keys you have for using MindPulse. You can also review our terms of use and check the number of remaining credits available to you.

5.4.4. Notifications

The “Notifications” section is automatically updated each time you use and administer MindPulse to a patient. This section allows you to check the status of the tests you have administered. You can mark notifications as read or unread based on your preferences.

5.4.5. Advice on Use

The “Advice on Use” section allows you to download a summary of the optimal conditions for using MindPulse (see Figure 7).

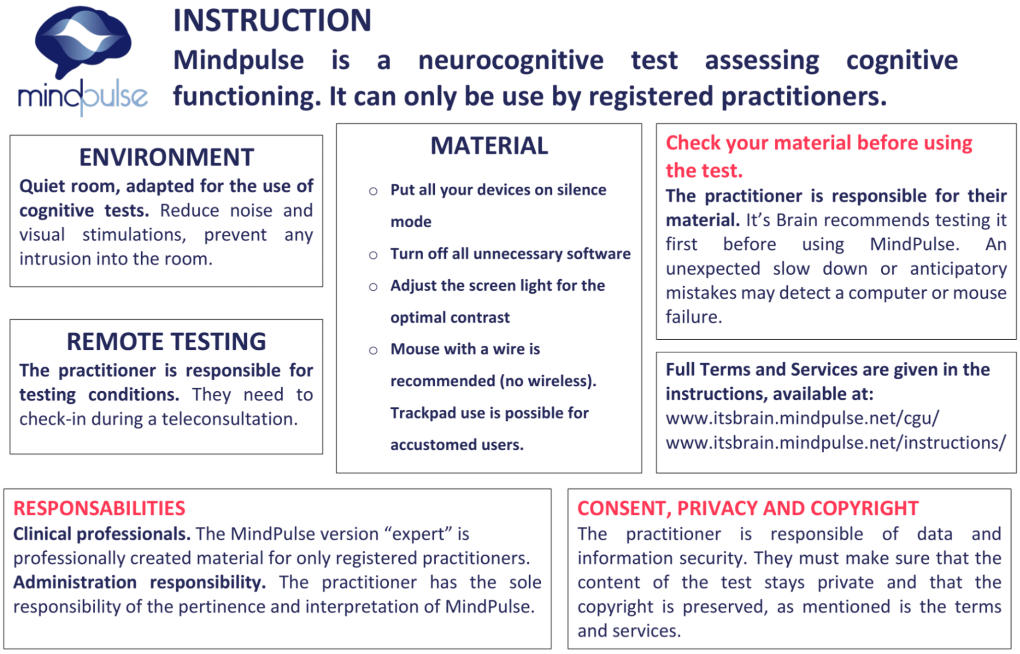


Figure 7. Advices on Use

6. Utilization of Mindpulse software

If you do not have a stable internet connection while using MindPulse, an offline version of the software is also available. This version requires manual installation of the software on your computer. Results can then be sent manually when your internet connection allows, or automatically at the end of the test if the connection is sufficient.

The Company implements all appropriate measures to ensure the security of data on the software and within the services offered and sold (obligation of means). In case of data loss, the Company shall not be held responsible for any damage caused by the loss of data. It is the user's responsibility to ensure data backup before installing the software and with each use. The MindPulse software does not contain any "viruses," but its use may be blocked by some antivirus programs and other firewalls of users. Users are responsible for the actions on their computer to allow the installation of MindPulse. The Company, It's Brain, cannot be held responsible for damages related to the functioning of other software besides MindPulse.

6.1. Installation protocol

The installation of MindPulse is quite straightforward. After accessing the download page at: https://www.mindpulse.net/en/telechargement-cliniciens/, the clinician starts by downloading the documentation related to installation and results reception by clicking on the "cloud" icon. These documents provide a step-by-step guide for installation procedures for both in-person and remote assessments.

The clinician can then download MindPulse by clicking on the icon corresponding to their computer system (Windows or Macintosh). The download will start immediately.

6.1.1. Macintosh

If you have a Macintosh computer, click on the Mac icon to download the corresponding installation file.

- Double-click on the downloaded .zip file and start the installation by clicking "Continue".
- Choose the destination for saving the installation before pressing "Continue".
- Select the type of installation to perform. It's Brain recommends a standard installation by simply clicking "Install". After a few seconds, the installation will be complete.

Note: Your computer may block the installation of MindPulse because it does not recognize the application. An error message may appear indicating that the application is not from an identified developer. If this message appears, click "OK", then click on the file while holding down the Command ⌘ key. To confirm your action, the computer will ask you to enter your administrator password before you can proceed with the installation.

Once the installation is complete, MindPulse is ready to use. However, you will need to click on the activation key received by email to use it. We recommend placing this activation key directly on your computer screen to use it as the MindPulse "icon".

6.1.2. Windows

If you have a Windows computer, click on the Windows icon to download the corresponding installation file.

- Double-click on the downloaded .zip file to extract the .exe file for the installation wizard.
- Click on the .exe file to start the installation process.
- Allow the application to make changes to your computer, then confirm the language choice by clicking "OK".
- Choose the user by clicking "Next".
- Complete the installation by clicking "Install" before closing the window by clicking "Next", then "Finish".

Note: Windows SmartScreen might block the start of the installation. If this happens, click on "More info", then "Run anyway".

MindPulse is now installed and ready to use. To launch it, double-click on the activation key received by email.

Once the installation is complete, MindPulse is ready for use. However, you will need to click on the activation key received by email to use it. We recommend placing this activation key directly on your computer screen to use it as the MindPulse "icon".

6.2. New test

To start a new MindPulse test, simply click on the software icon and then click on "Start Test." The test will begin automatically after entering the participant's personal information and checking the various conditions of use.

6.3. Data Transmission

At the end of the test, and if it was conducted under optimal conditions, the clinician can either directly and automatically send the patient's data to It's Brain to receive the report or save the results to request a report at a later time.

6.3.1. Automatic transmission

Automatic submission requires an internet connection and at least one report credit remaining. If you choose automatic submission, after noting the test conditions, simply click on "Obtain a report" at the very end of the test. You will then receive an email within a few minutes containing a unique link allowing you to download your report from a secure space.

6.3.2. Manual Transmission

If the clinician decides not to request a report immediately after completing the MindPulse test, the recorded data will remain accessible for a report request later, but it will need to be submitted via the manual procedure. The manual procedure is described in the downloadable documentation available on the website www.mindpulse.net/en/telechargement-cliniciens/.

In the manual procedure (Figure 8), the clinician needs the patient's identification code to request the results. This code is accessible through the application under "view the list of patients." Once obtained, the clinician must return to the test homepage and click on "open file." They then select the file corresponding to the patient for whom they wish to obtain the results. The clinician attaches this file, without renaming it, in an email addressed to "resultats@mindpulse.net." An automatic receipt confirmation will be sent immediately by MindPulse. The report will then be downloadable via a unique link, which will also be sent by email.

Figure 8. How to send the results to Mindpulse : manual procedure

6.4. How to find a patient's personal information ?

To manually send data when using the MindPulse software, or simply to verify the correspondence between your patient's code and their name, you may need to access the non-anonymized MindPulse information. This information is available on the clinician's space of MindPulse Online when it has been used for testing, and on your computer when using the MindPulse Software.

Consulting the correspondence between your patient's personal information and their MindPulse code is possible on the MindPulse Software. To do this, simply open the software and click on the "View the list of patients" button. You will then find a table of all your patients, including their personal information and their patient code (see Figure 9).

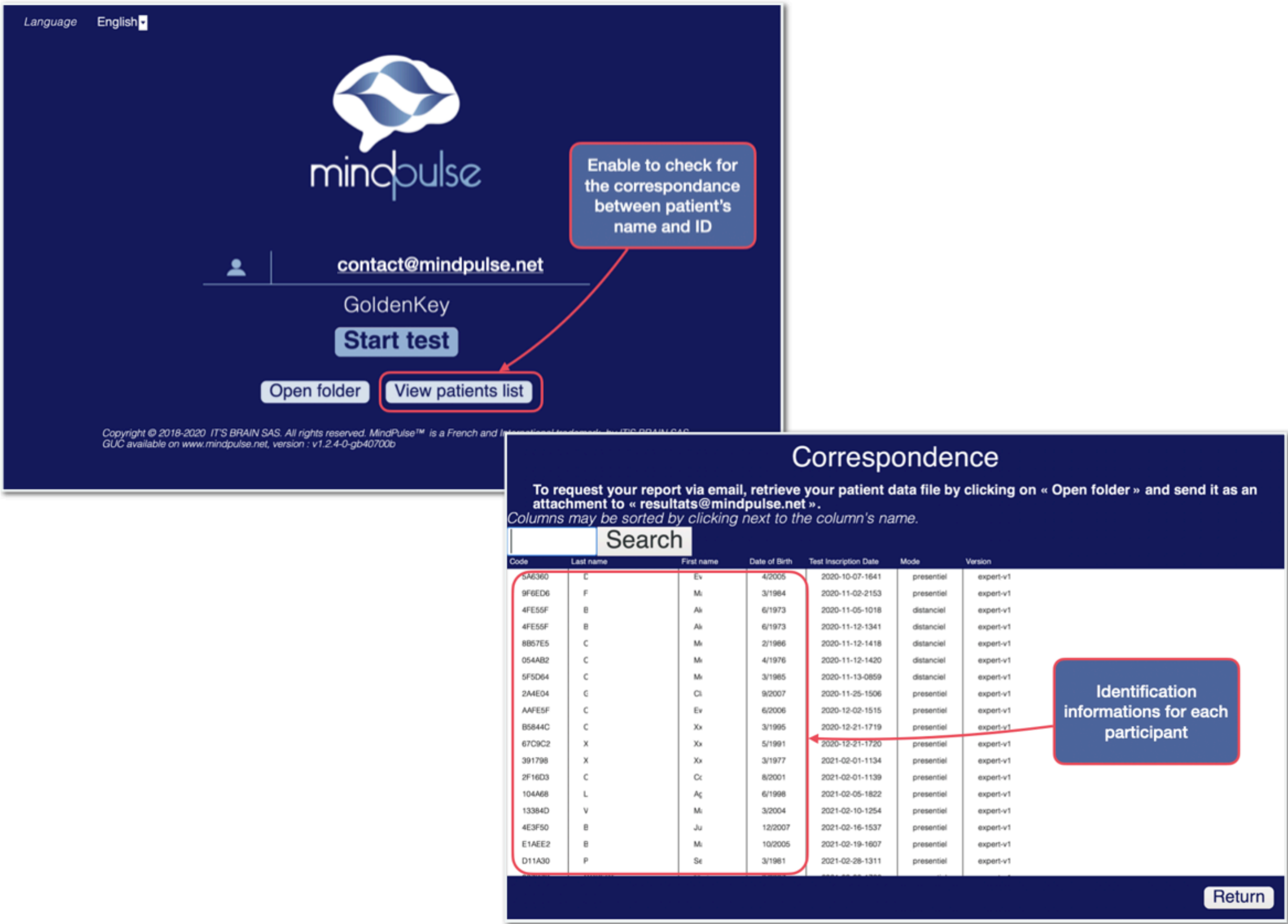


Figure 9. a) Access to the table linking the clinician code with the patient identification information from the MindPulse homepage.
(b) Table linking the patient code with their personal information: name, first name, date of birth, date of the test administration, and mode of administration (remote or in-person)."

7. New test MindPulse

7.1. Participant Informations

Starting the test requires entering information about the participant being tested. The necessary information is as follows:

- The patient's first and last name
- Their gender
- Their laterality

- Their date of birth
- Their level of education
- Their native language(s)

This information will be used to generate a unique patient identification code, ensuring their anonymization.

7.1.1. Terms and Conditions

The test begins with the confirmation of the general conditions of administration by checking a box. The participant is reminded that their personal information (name, date of birth, etc.) is not transmitted to It's Brain. The participant acknowledges that they are being supervised by a clinician during the test and agrees not to receive any results directly from It's Brain. The participant consents to the transmission of the test data to It's Brain for the interpretation of the results.

7.1.2. Testing protocol

Once the administration conditions are validated, the test automatically switches to full-screen mode, and a test introduction window appears. The instructions follow, presenting a guideline on the computer that the participant should take the time to read (see Figure 10).

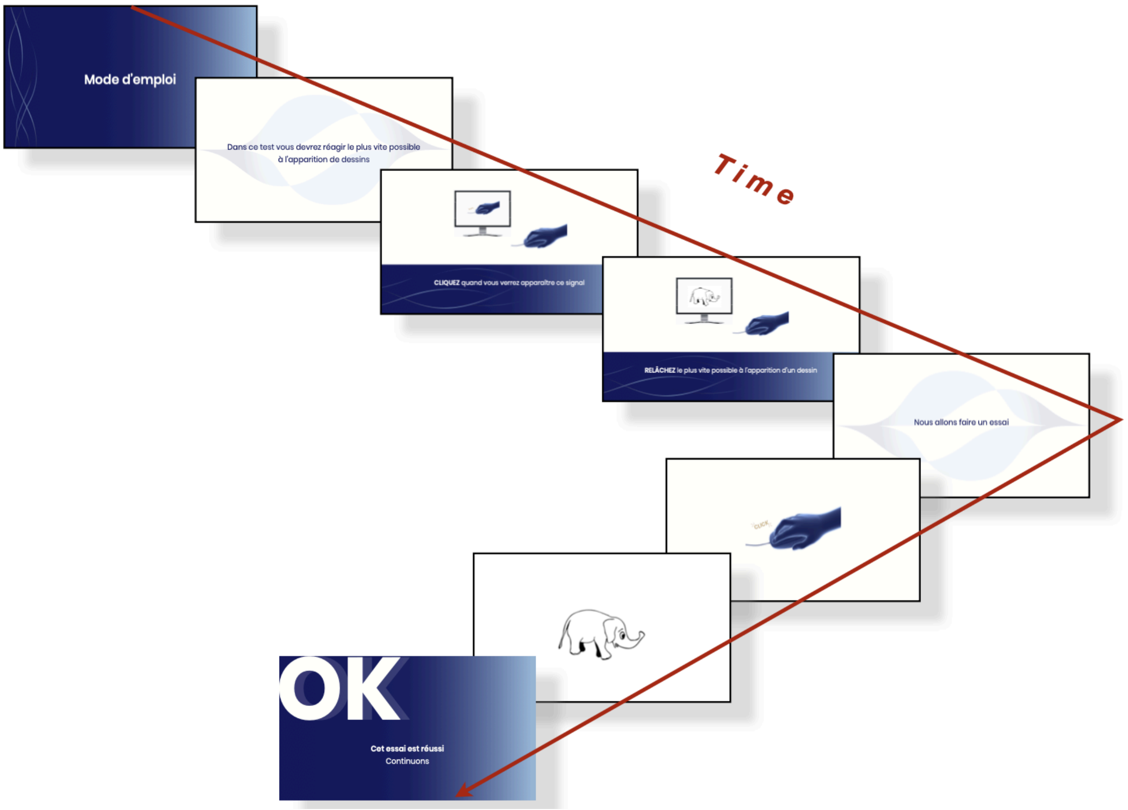


Figure 10. Test procedure on SRT

Understanding the instructions is crucial for the proper use of MindPulse. Since reading the instructions alone may sometimes be insufficient, it is essential that the examiner verbally re-explains the instructions, with additional repetitions or clarifications if necessary, to eliminate any risk of misunderstanding.

After reading and confirming the participant's understanding of the instructions, a window will open where a preliminary trial will be conducted to teach the gesture necessary for the test (click - release).

Success in this gesture-learning trial is required to proceed with MindPulse. Once this prerequisite is met, the first phase of the test, corresponding to simple reaction time (Part A - SRT), begins with its 4 training trials. For each trial, the participant is asked to press the mouse button when a "click" symbol appears and to hold down the click. The screen then turns white, and the participant should release the click upon the appearance of the target image. In the SRT (and its training), the participant must release the click for all images without distinction. Success in the training is necessary to access the test phase. Training can be repeated in case of failure, up to 3 times. As in each section, instructions are reiterated between the end of the training and the start of the evaluation.

Once the SRT is completed, the participant clicks on “Next” to continue the test and proceed to the explanation of the instructions for the second part, which corresponds to a 1-choice reaction time (RT1C) or simple Go/NoGo (RT1C). In this part, the participant should only release the click for relevant images, depending on their color. A 4-trial training session, which can be repeated up to three times in total, is presented again and must be completed successfully (at least 3 out of 4 correct) to start the Go/NoGo simple evaluation part.

At the end of the RT1C, the participant clicks on “Next” to proceed to the third and final part of the evaluation. The instructions for RT2C (1-choice reaction time), or complex Go/NoGo, are explained before the training begins. In this part, the participant should only release the click if the image meets both simultaneous criteria of color (white/gray) and type (living/non-living). The participant releases the mouse only if the image matches both simultaneous criteria. Success in the training is always required to continue the test. The MindPulse test concludes after the 20 trials of this part.

7.1.3. Completion of the Test & Data Submission

At the end of the test, a final window opens to thank the participant for their participation. The participant is asked to evaluate the quality of the test administration with the clinician, and a space is provided for comments on the conditions of the test. Finally, the patient code is displayed (Figure 11).

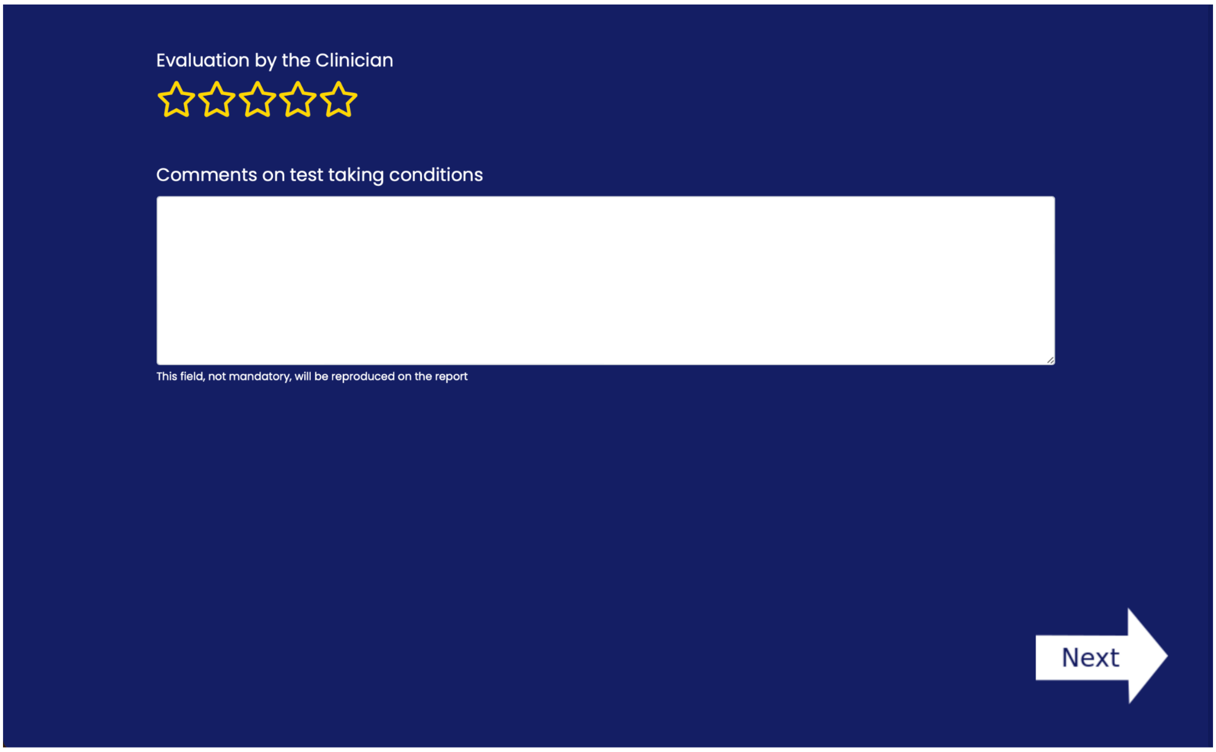
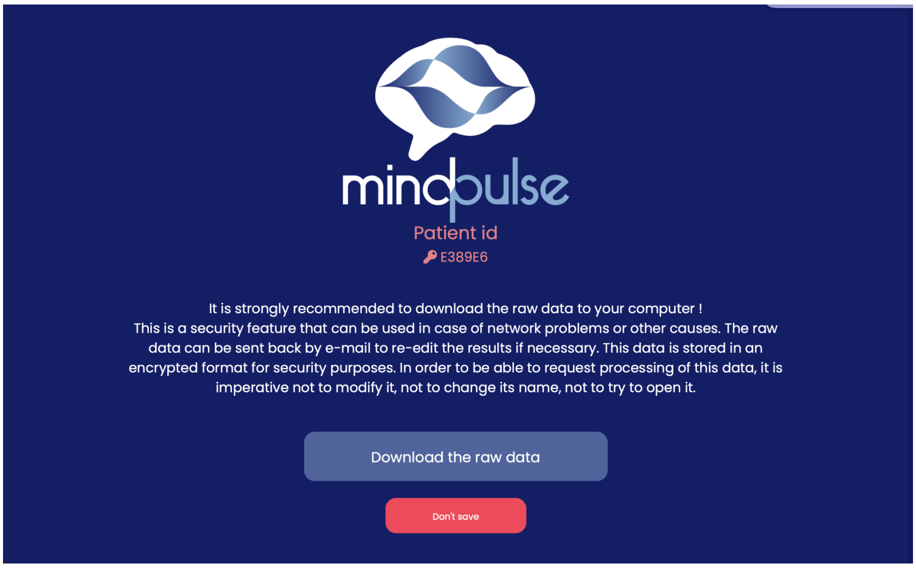
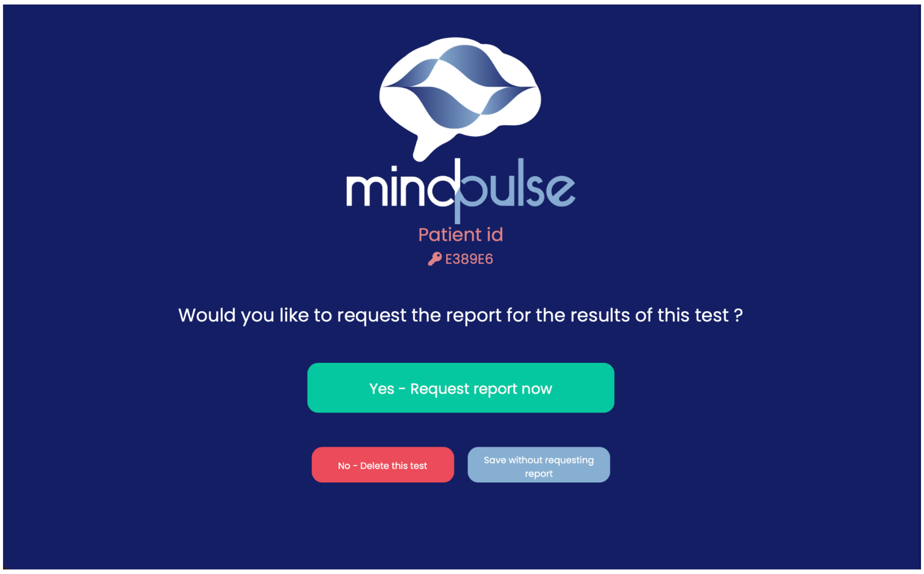


Figure 11. How was the passation ?

Once the fields are filled in, the results can be sent by clicking the corresponding button or saved to be sent later. It is imperative to complete the procedure by choosing one of these options so that the results are recorded and can be processed for a report (Figure 12 a, b, and c). In all cases, when the clinician decides to submit the results, they will receive an email with a download link for their report after a few minutes.





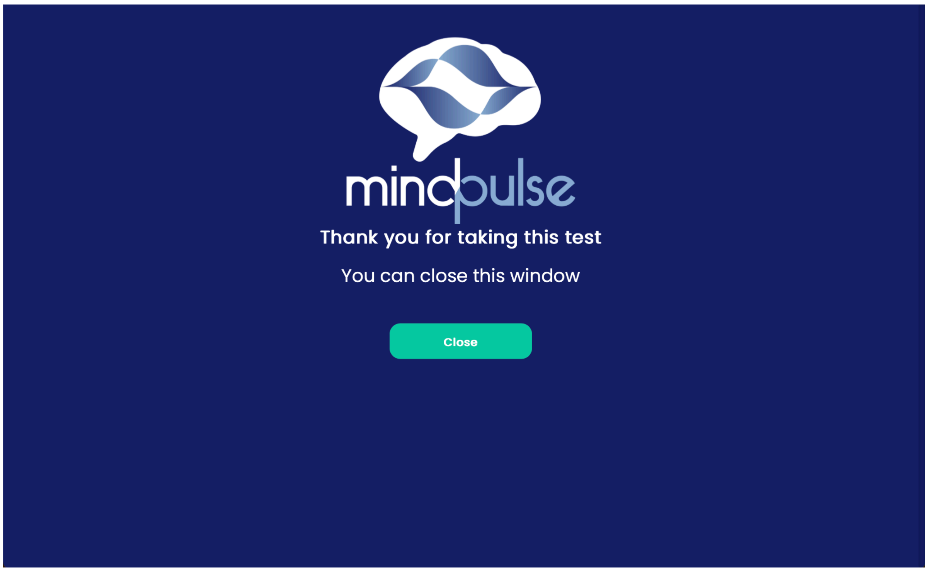


Figure 12. Successive screens to save, process, and end a MindPulse test

8. How to choose the testing protocol ?

It is always preferable to administer the MindPulse test in person with your patient. However, in certain cases, you might prefer a remote administration. We have made this possible, but keep in mind that it is your responsibility as a clinician to ensure the proper conditions for the test administration by your patient. Therefore, we recommend verifying in advance that the appropriate conditions are met and to use MindPulse remotely only within the framework of a teleconsultation with visual monitoring of the test administration via a separate device from the computer where MindPulse is installed. MindPulse emphasizes that the MindPulse standards were developed by clinicians in in-person settings.

We remind you that adhering to proper administration conditions is crucial to ensure the accuracy of the results and their interpretation. These conditions include:

- A quiet room, without interruptions or auditory or visual disturbances
- A computer that supports the use of the MindPulse software or online version
- A wired mouse
- A comfortable and suitable position

We recommend that the clinician close all other applications or software running on the computer used for the MindPulse administration to allocate maximum processing power to MindPulse and to avoid unwanted interruptions.

8.1. Remote Administration

8.1.1. Consent, Confidentiality, and Copyright

We remind you that the clinician is responsible for the security of the data and information provided to the patient (or the responsible adult, if applicable) as well as for obtaining informed consent from the patient or the legal guardian of the patient.

The clinician is also responsible to It’s Brain for ensuring the confidentiality of the test content and for not violating copyright, as stated in the terms and conditions of use. These terms and conditions apply whether the test is administered in person or remotely. The clinician is therefore responsible for informing the patient and the trusted third party about confidentiality conditions, including the prohibition of recording or photographing any part of the test, and ensuring that the confidentiality of MindPulse content is maintained.

The home evaluation should replicate a situation as close as possible to the in-office evaluation, especially in terms of providing an appropriate environment.

8.1.2. Via MindPulse Online

In the case of remote use, your patient will automatically receive a link via email that allows them to access the test directly in their browser. No download will be necessary. At the end of the test, the patient will simply need to click on the "Send Results" button and close the page. The results will be automatically transmitted and sent to the clinician, who will be able to access them through their MindPulse Online client space.

The patient will also have the option to save their results to their computer. We recommend performing this backup to ensure that results can be recovered in case of any connectivity or email issues.

8.1.3. Via MindPulse software

8.1.3.1. Patient Software Installation

Using the MindPulse software remotely requires the patient to first install the MindPulse application on their computer. It’s Brain recommends performing this installation before the scheduled consultation to ensure that the patient will be able to use the test effectively.

The patient should download the installation file and the installation guide for MindPulse from the following link:
https://www.mindpulse.net/telechargement-patients/

After downloading the file for their specific computer system, the installation procedure is identical to that performed on the clinician’s computer. Once installed, a shortcut icon will appear on the patient's desktop. To verify the installation, the patient should double-click the icon to launch the application. A message will then prompt them to use the activation key.

8.1.3.2. Remote Test Administration

At the time of the teleconsultation, the clinician sends the activation key to the patient, which they have previously received by email, so that the patient can double-click on it to start the test.

At the end of the test, the patient saves their results and must manually email them to the clinician. The clinician will then need to manually email the patient’s results to MindPulse in order to obtain the report.

9. Interrupting the Test During Administration

In case of issues during the administration of MindPulse (such as abnormal fatigue, questions, etc.), and at any moment, the test can be temporarily or permanently interrupted by pressing the "Escape" key (or "Esc").

The MindPulse

MindPulse is a digital neurocognitive test that measures the fundamental decision-making process and its various subcomponents.

MindPulse uses psychomotor slowing as an indicator of neurocognitive functioning, with each individual being their own benchmark. The test relies on precise measurement of the subject's reaction times (response time: RT) to the hundredth of a second, and on the accuracy of responses. The subject's adaptation, necessary to succeed in the different parts of the test where complexity and attentional demand increase, leads to a slowdown in their response.

MindPulse thus measures various components of decision-making by considering executive and attentional balance. It provides insights into the intensity of attention, attention selectivity and stability; executive control, inhibition of automatic responses (impulsive and compulsive behavior); and engagement in the task (Figure 13). Through an innovative design, MindPulse also offers new indicators of functioning, such as executive speed and reaction to difficulty.

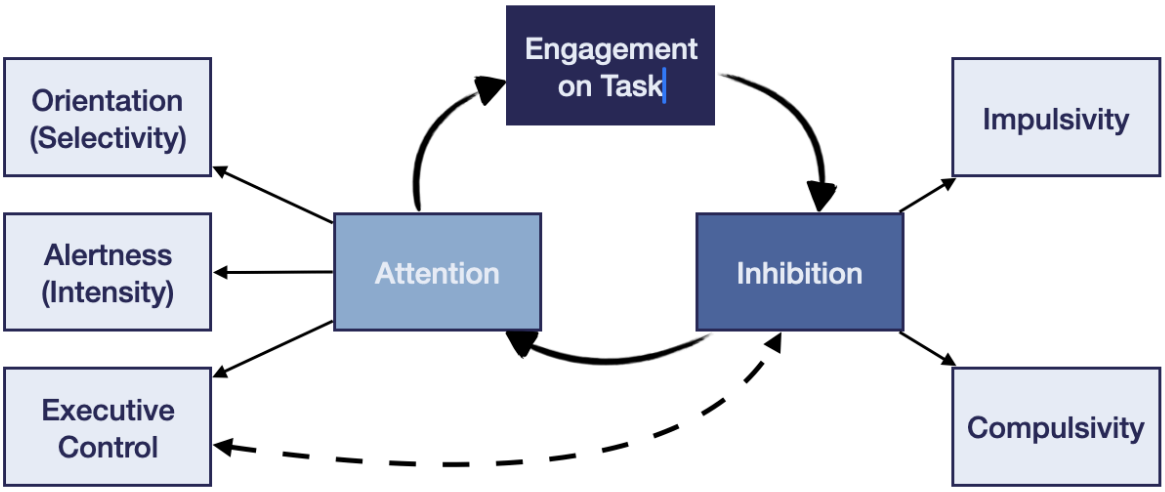


Figure 13 : Decision-making sub-components evaluated in MindPulse

1. The Three parts of MindPulse

MindPulse is structured into three successive and increasingly complex trials. The difficulty level of the third trial is calculated based on projections from the first two trials, and the data is adjusted accordingly.

In each of these trials, the subject prepares for action by pressing the mouse click and reacts to the appearance of an image according to the instructions by releasing the mouse button.

Regardless of the part of the evaluation (A or TRS, B or TR1C, and C or TR2C), the testing conditions remain the same: only one stimulus is presented on the screen at a time, and the action performed is to release the mouse button upon the appearance of a target image.

Only the instructions change from one condition to another, becoming more complex by first integrating a categorization request (in Go/NoGo - Part B), and then a request for simultaneous double categorization and inhibition (complex Go/NoGo - Part C - Figure 14).

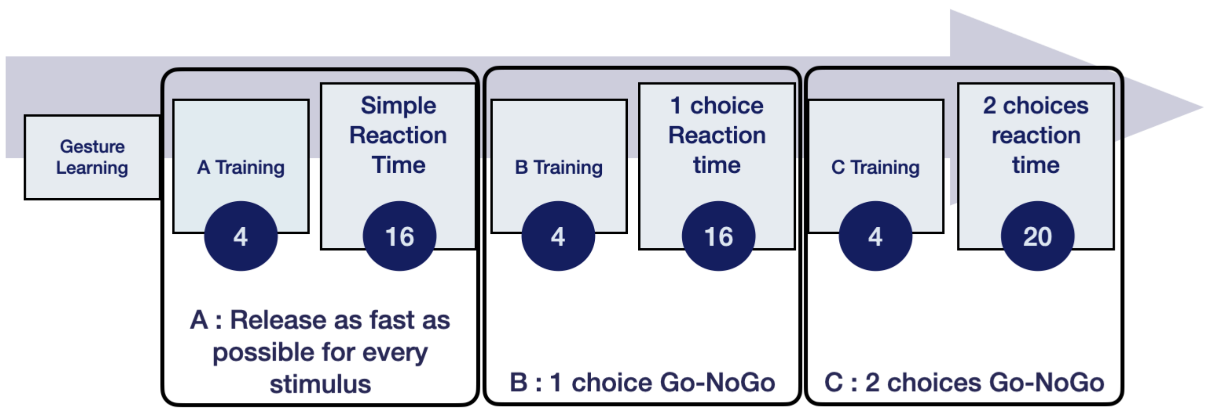


Figure 14 : MindPulse subsections following time, and including number of trials within each parts.

1.1. Training trials

Before each part, the subject undergoes a training session. Success in this training, consisting of 4 trials, is necessary for MindPulse to continue with the evaluation. To pass the training, the subject must succeed in 3 out of 4 trials. In case of failure, the training procedure is repeated up to a maximum of 3 times. If the subject does not succeed after 3 attempts, MindPulse will be terminated (Figures 14 and 15).

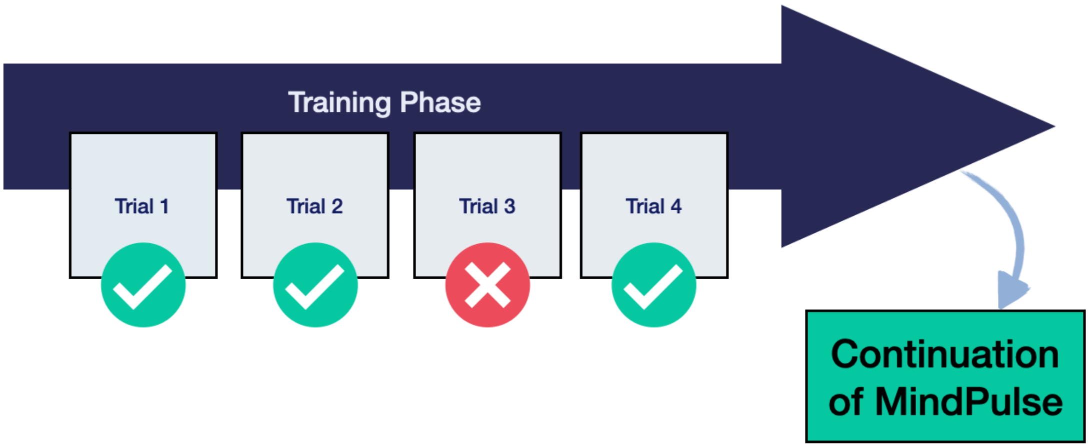


Figure 14 : Schematic representation of training phases: Case of success in the training phase.

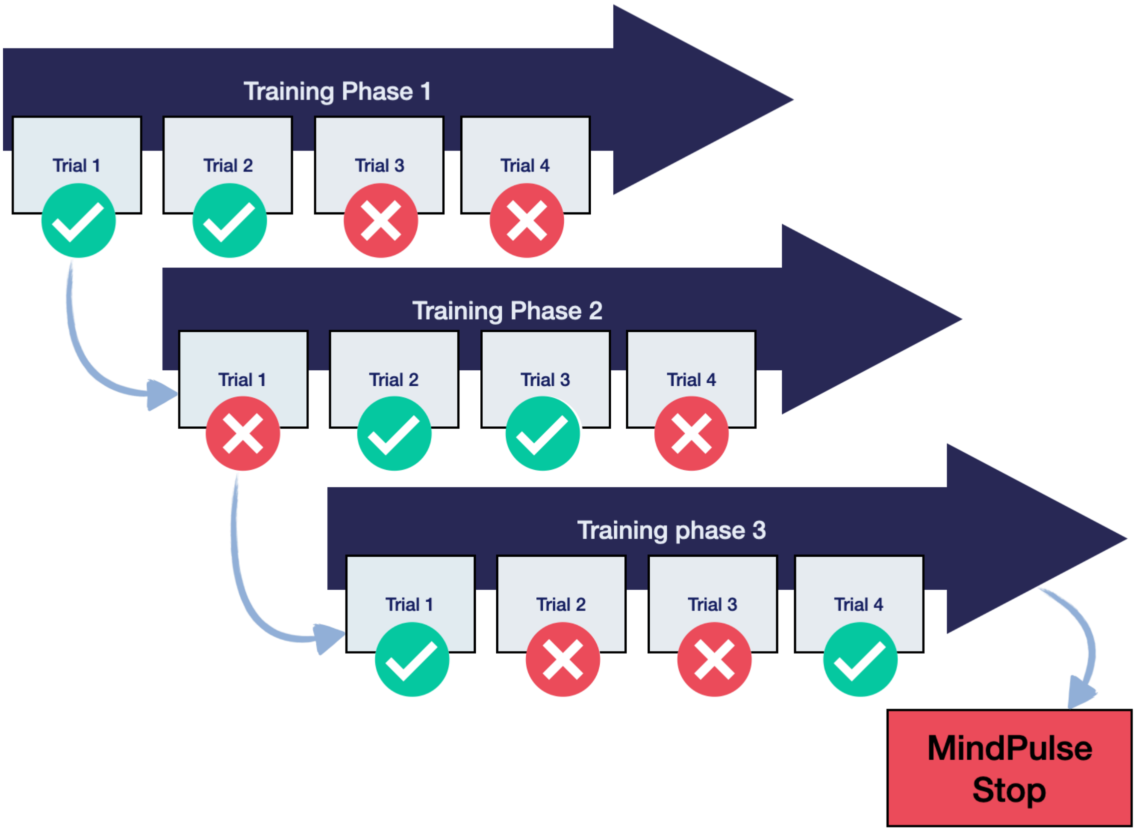


Figure 15 : Schematic representation of training phases: Case of failure in the 3 consecutive training phases.

1.2. Learning the Release Gesture

MindPulse is based on the principle of releasing the mouse click upon detecting a stimulus that meets the specific criteria of each part of the test. To familiarize the subject with this gesture, a single training trial for the release gesture is offered at the very beginning of MindPulse. This phase introduces the MindPulse instructions and provides the participant with their first opportunity to click when a click sign appears, hold the click during the blank screen, and release it upon the appearance of the image. If this step is not completed successfully, it is repeated as many times as necessary until it is successfully performed.

1.3. Part A : Simple Reaction Time (TRS)

The TRS (Simple Reaction Time) is the first test in MindPulse, where the subject must react as quickly as possible to the appearance of an image, without any other criteria. The subject starts by pressing the mouse click at the start signal, and then releases the click as soon as a new image appears. This part measures the perceptual-motor disengagement time and provides a measure of simple perceptual-motor speed. This section consists of 16 trials, in addition to 4 training trials.

In this part, there is no choice error possible; the subject should release the mouse regardless of the image. However, they may produce Omission Errors (not reacting to the appearance of an image) and Anticipation Errors (reacting before the image appears or within 100ms of its appearance). Omission Errors are extremely rare and should always be considered abnormal in this condition. Anticipation Errors are generally associated with impulsivity but can also be linked to motor disorders (motor weakness).

The TRS score corresponds to the smoothed median score of the successful trials. Given the number of items in the test and their asymmetric distribution, the median is a more appropriate parameter than the mean, which is less valid. Outlier responses are weighted using Gaussian smoothing. This smoothing helps mitigate the potential impact of an adverse event during the test. However, frequent occurrences of such responses will increase their weight in the TRS calculation. In this way, the TRS better represents the subject's typical reaction times. The TRS is then corrected according to the subject's age and sex. If the “other” box for sex was checked in the preliminary information, normalization according to sex will not be performed.

1.4. Part B : Go/NoGo - 1 choice reaction time (TR1C)

The Reaction Time with 1 Categorization, or Simple Go/NoGo test, is the second test in MindPulse. The subject must release the mouse click only if the image that appears corresponds to the requested category (Go). This category depends on the color of the item, either gray or white. The color choice is made randomly by the computer and remains constant throughout the condition.

The participant should release the mouse click only if the stimulus matches the requested color criterion. If the image does not match, the participant should not release the mouse click (No-Go) and should wait for a trial end signal before releasing. This test also consists of 16 trials, in addition to the 4 training trials.

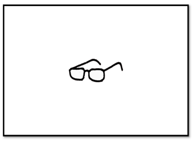
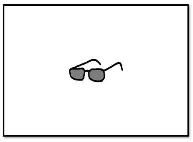
1.5. Part C : Complex Go/NoGo - 2 choices reaction time (TR2C)

The third and final part of MindPulse, also known as TR2C (Reaction Time with 2 Categorization), is a complex Go/NoGo test involving simultaneous double categorization. In this part, the subject must react (release the mouse click) only for stimuli that simultaneously match two requested categories.

The color criterion is always reversed compared to part B, requiring inhibition of the previously relevant color. The second criterion, which is new, refers to whether the stimulus is living or non-living. The selection of the relevant criterion for this new category is random.

This test consists of 20 trials, in addition to the 4 training trials.

2. Stimuli

The images used in MindPulse are grouped into 2 criteria, each with two modalities:

- **Color:** “White” vs “Gray”
- **Category:** “Living” vs “Non-living”

Each item in the category (Living / Non-living) exists in both a white version and a gray version.

3. Descriptions of the scores

MindPulse measures various parameters of decision-making. These are described in the report sent to the clinician. The analysis notes, available at the end of each report, help the clinician interpret the results. The perceptual-motor decision-making process involves several components that MindPulse can measure:

- **Simple Reaction Time with Release (TRS - Part A)** is measured during the first test of MindPulse, where the subject must release the mouse as quickly as possible upon the appearance of an image. TRS represents the perceptual-motor reaction time to the appearance of an image. It indicates the time needed for the perception and analysis of the image, as well as the planning and execution of the motor action of releasing the mouse.
- **Go / No-Go Score (for B & C)** is part of the overall results of MindPulse. It corresponds to the time required to perform simple categorization (1 choice, B) and complex categorization (2 choices, C) in MindPulse. In addition to the perceptual-motor aspect, these two conditions involve semantic processing of the perceived image to determine if it meets the categorization criteria. The subject must make a categorization decision about these images to generate (Go) or not generate (NoGo) a motor response (mouse click).

- **Executive Speed (ES)** refers to the time needed to perform cognitive processing of decision-making and image categorization in the TR1C and TR2C tests, after removing the perceptual-motor time. Executive Speed (ES) provides an indication of pure cognitive processing speed, without motor involvement. This index allows the study of the contrast between a simple (TRS) or reflexive motor condition and a more complex condition requiring mental operation execution.

ES score	ES= ((TR1C-TRS)+(TR2C-TRS))/2).

- **Reaction to Difficulty (RD):** This measures the subject's adjustment to difficulty and depends on the balance between "going fast" to meet the categorization demands and "making as few errors as possible." Due to the increased difficulty from TR1C to TR2C, it is expected that reaction times will increase in direct correlation with this growing complexity. MindPulse measures the expected and normal level of slowing for each subject based on their previous responses, making each subject their own control. If the slowing is greater than expected, the RD index increases. Conversely, if the slowing is less than expected or absent, the RD decreases. A variation in RD indicates an imbalance between the speed and accuracy of the response.
- **Dispersion:** The dispersion of response times measures the variability in subjects' response speeds. Significant dispersion suggests considerable variability in reaction times and may indicate attention fluctuations or external factors disrupting concentration.
- **Error Analysis:** Various types of errors are measured in MindPulse:
    - **Total Errors** refer to all errors, of any nature, committed during the entire MindPulse assessment.
    - **Anticipation Errors** occur when the subject responds (clicks) prematurely, either before the image is presented or within 100ms after the appearance of the stimulus. These are generally indicative of impulsivity.
    - **Omission Errors** are divided into two subcategories, depending on whether they occur during TRS or during TR1C and/or TR2C. These are cases where the subject fails to respond to an image for which a response was expected.

    - In TRS, omission errors are rare where the subject does not react to an image within 3 seconds of its appearance. These errors are generally associated with lapses in attention, difficulty understanding the instructions, or technical (mouse malfunction) or environmental (disruptive event) issues.
    - In TR1C and TR2C, omission errors occur when the subject does not respond to an image that meets the categorization criteria. These errors may be linked to lapses in vigilance or executive difficulties related to categorization.
- **Incorrect Responses** are commission errors occurring during categorization tests (TR1C and TR2C). The subject responds to an image that does not meet the categorization criteria. The participant makes a mistake about the requested category. These errors are termed “active” and are often associated with executive difficulties, particularly cognitive flexibility.
    - In TR2C, several types of incorrect responses are noted:
        - **Inhibition Errors** are errors related to color. In TR1C, individuals must categorize images based on their color (light or dark). In TR2C, the color criterion is reversed (e.g., if in TR1C the subject reacts to light images, in TR2C they must react to dark images). When the subject reacts to the wrong color in TR2C, they have persisted with the previously relevant color.
        - **Overload Errors** are related to the new categorization criterion of TR2C: the living or non-living nature of the image. When the subject makes an error regarding this criterion (and thus responds to the wrong category regarding living), it is considered an overload error. The addition of a new category overwhelms the participant's cognitive and executive capacities, preventing effective processing of the new categorization.
        - **Joint Errors** are errors made in both categories simultaneously: the subject responds to images that do not match either the target color or the living or non-living character. When these errors are too frequent, it is important to question the understanding of the instructions. High

impulsivity and major inhibition deficits could also contribute to an increase in these errors.

- **Aberrant Responses (Ab)** are correct responses but are made in abnormally long times (<2 standard deviations) compared to the subject's average response times. They are generally indicative of attentional lapses. A single aberrant response is generally normal; however, frequent occurrences throughout the test can indicate an attentional disorder or a more general problem in maintaining sustained attention.

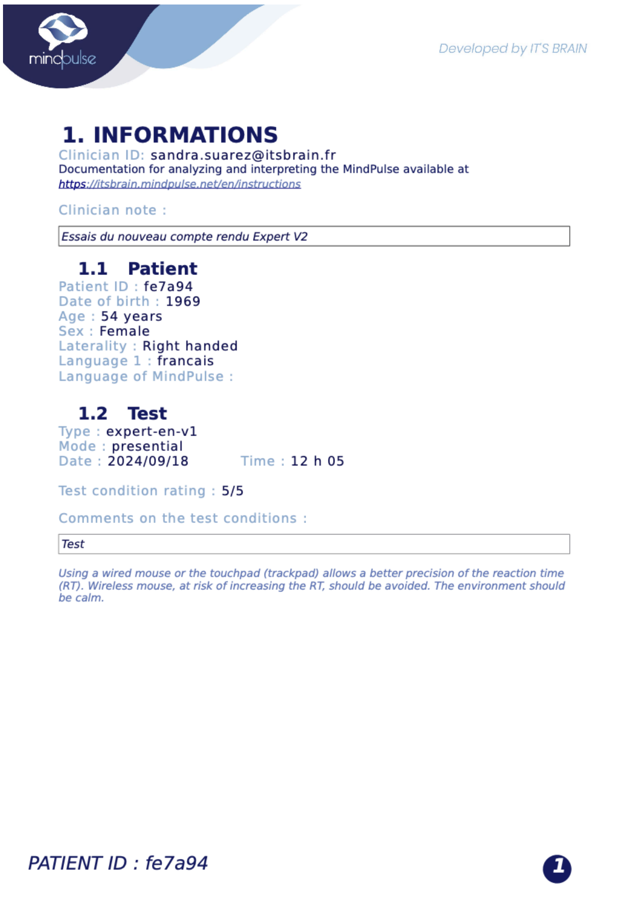
4. The MindPulse Report

4.1. Reminder

MindPulse is based on the fine detection of the subject's response time within a "speed/accuracy" trade-off. For each of the three conditions (A, B, and C), the subject must respond by releasing the mouse click as quickly as possible, without risking going too fast and making errors. The subject adjusts to these various parameters throughout the test. **MindPulse** allows for the measurement of this adjustment across different axes. The report provided by **It's Brain** following the receipt of the patient's test data presents the main and detailed results. Its various sections are outlined below.

4.2. Page 1 : General Information

The first part of the report (Figure 16), on page 1, relates to the general information of the clinician and the subject. The clinician's name and code are listed, followed by the anonymized information of the patient. This section includes the subject's identifier (Patient ID), date of birth, age, gender, handedness, and native language(s). Lastly, the time and date of the **MindPulse** test are noted, along with the clinician's assessment of the test quality and any additional comments they may have.


Developed by IT'S BRAIN

1. INFORMATIONS

Clinician ID: sandra.suarez@itsbrain.fr
Documentation for analyzing and interpreting the MindPulse available at
https://itsbrain.mindpulse.net/en/instructions

Clinician note :

Essais du nouveau compte rendu Expert V2

1.1 Patient

Patient ID : fe7a94
Date of birth : 1969
Age : 54 years
Sex : Female
Laterality : Right handed
Language 1 : francais
Language of MindPulse :

1.2 Test

Type : expert-en-v1
Mode : presential
Date : 2024/09/18 Time : 12 h 05

Test condition rating : 5/5

Comments on the test conditions :

Test

Using a wired mouse or the touchpad (trackpad) allows a better precision of the reaction time (RT). Wireless mouse, at risk of increasing the RT, should be avoided. The environment should be calm.

PATIENT ID : fe7a94 1

Figure 16 : First page of the report

4.3. Page 2 : Perceptivo-motor decision making Balance

The "Perceptual-Motor Decision-Making Balance" chart (Figure 17) forms the first part of the results. Acting quickly and accurately requires the subject to strike a balance: they need to find the "right speed" at which they can respond correctly. If they go too fast, the risk of errors increases. The ideal speed changes depending on the complexity of the task, and the subject must adapt. The goal of this chart is to show, at a glance, the subject's positioning on four fundamental axes of this speed/accuracy balance.

The uniqueness of **MindPulse** is that the clinician can examine not only the patient's "basic" perceptual-motor speed (which includes the perceptual and motor component of releasing the mouse; TRS) but also their executive (or "ideational") speed (ES), stripped of the perceptual-motor component, while also taking into account the precision of the result (errors) and how they respond to perceived difficulty.

The evolution of slowing down is analyzed based on the individual's own measures, by subtracting the TRS (basic perceptual-motor release task) from the other two conditions to remove the perceptual-motor component. This way, each subject becomes their own reference regarding their perceptual-motor execution time. This deeper analysis allows for the creation of two novel indices: executive speed and reaction to difficulty. These indices, presented below, will be further detailed following the scientific publication of our data.

On the perceptual-motor decision-making balance chart, the subject is represented and located by a colored point of varying size. The interpretation of their performance depends on the color of the point, its size, its horizontal position, and its vertical position on the chart.

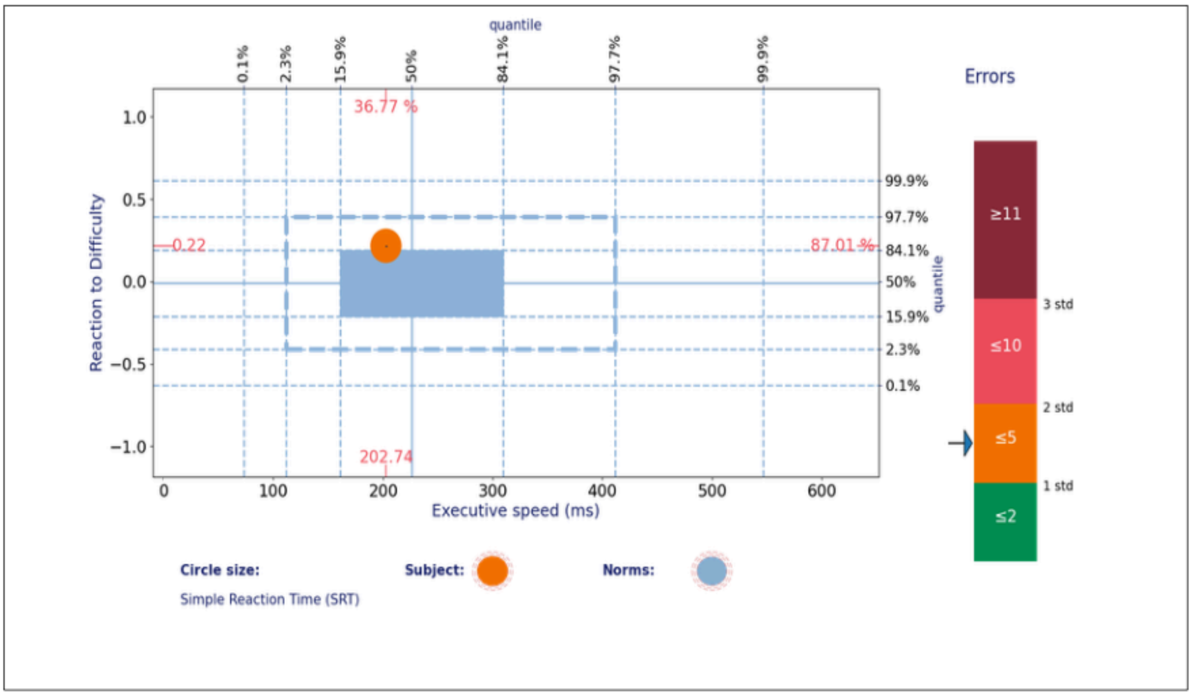


Figure 17 : Balance of perceptivo-moteur decision making

- The size of the circle (representing the subject) varies according to their Simple Reaction Time (TRS). The TRS, expressed in milliseconds, corresponds to the time required to perceive a stimulus and generate a motor response (releasing the mouse click). The subject's TRS should be compared to the reference average TRS, which is directly visible below the chart (Figure 18). Variations at +1 and +2 standard deviations are represented by the two outer circles. The larger the circle, the slower the subject.

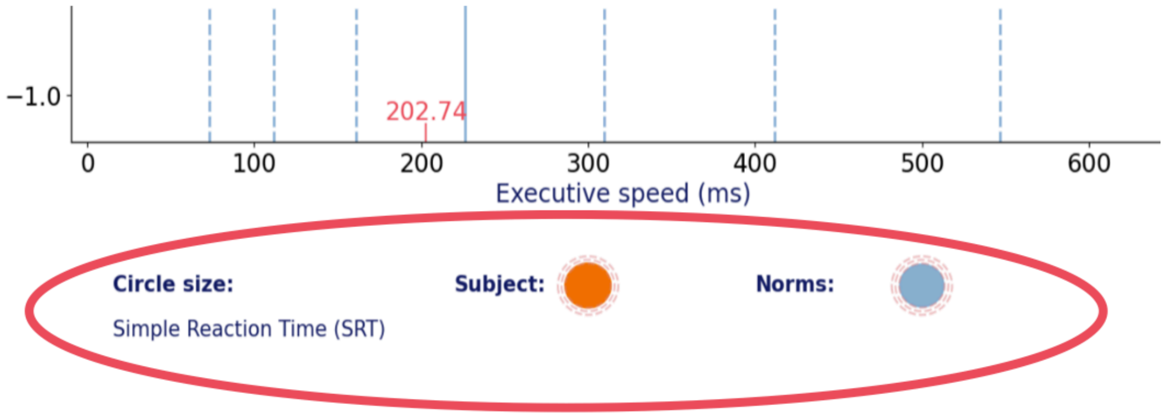


Figure 18 : Visualization of circle size related to perceptual-motor speed.

- The color of the circle allows for visualizing the number of Total Errors made by the subject during the MindPulse test. The color provides an indication of the subject’s accuracy across the three parts of the test. The legend corresponding to the colors is visible to the right of the chart (Figure 19). A green color indicates an error rate within the average range, orange corresponds to the borderline zone between 1 and 2 standard deviations, red corresponds to +2 standard deviations, indicating the pathological zone, and dark red represents

+3 standard deviations.

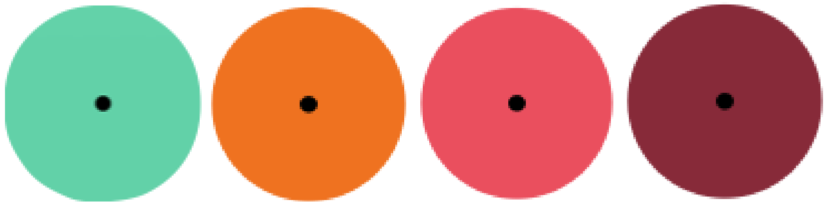
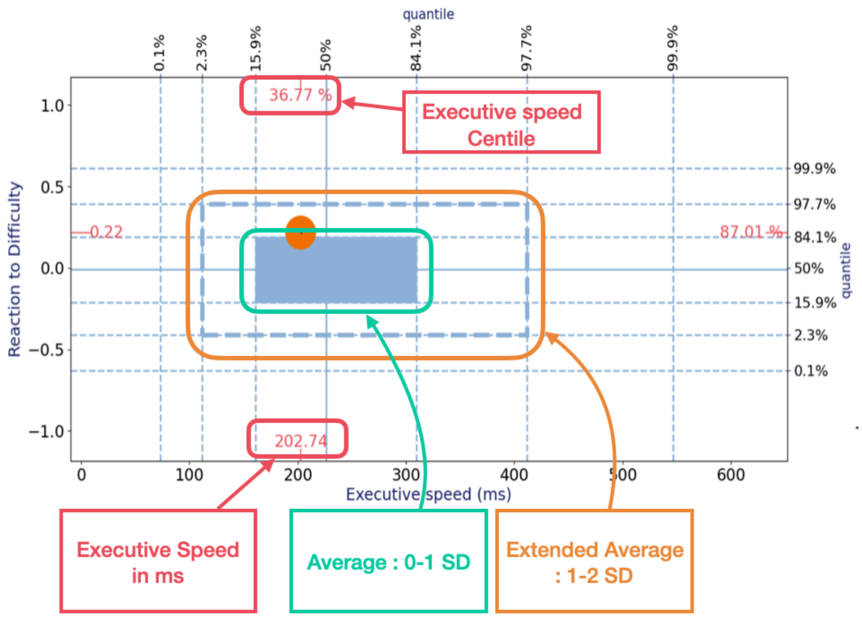


Figure 19 : Color Chart for accuracy

- The <u>position of the point on the x-axis</u> allows for visualizing the subject's Executive Speed. To recap, executive speed corresponds to the time taken for cognitive processing once the perceptual-motor time is accounted for. A slowdown in executive speed will result in the circle shifting to the right. The percentile rank of executive speed can be read on the upper part of the x-axis, which indicates the percentage of individuals with slower executive speed than the subject. The normal range, between zero and one standard deviation, is visible in the blue rectangle at the center of the chart. The extended normal range (upper and lower average), corresponding to the limit of two standard deviations, is shown by the dotted rectangle (Figure 20).



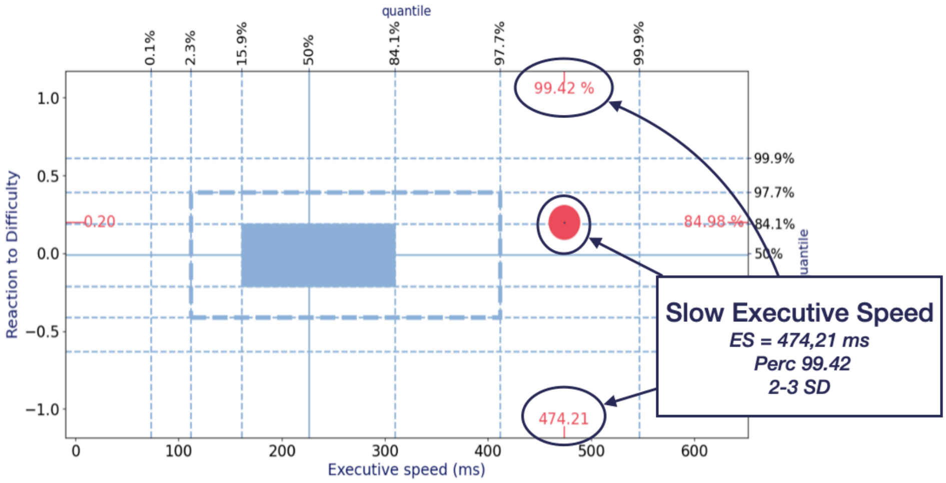


Figure 20 : Description of the areas related to executive speed.

- The vertical axis (ordinate) allows for visualizing the subject's reaction to difficulty, which corresponds to how they adjust to the increasing complexity of the tasks. Poor adjustment to difficulty can manifest either as excessive slowing (deceleration: the participant slows down too much in response to difficulty), visible by the point being positioned in the upper part of the graph, or as insufficient slowing (overspeed: the participant goes too fast in relation to the difficulty), with the point located in the lower part of the ordinate axis (Figure 21).

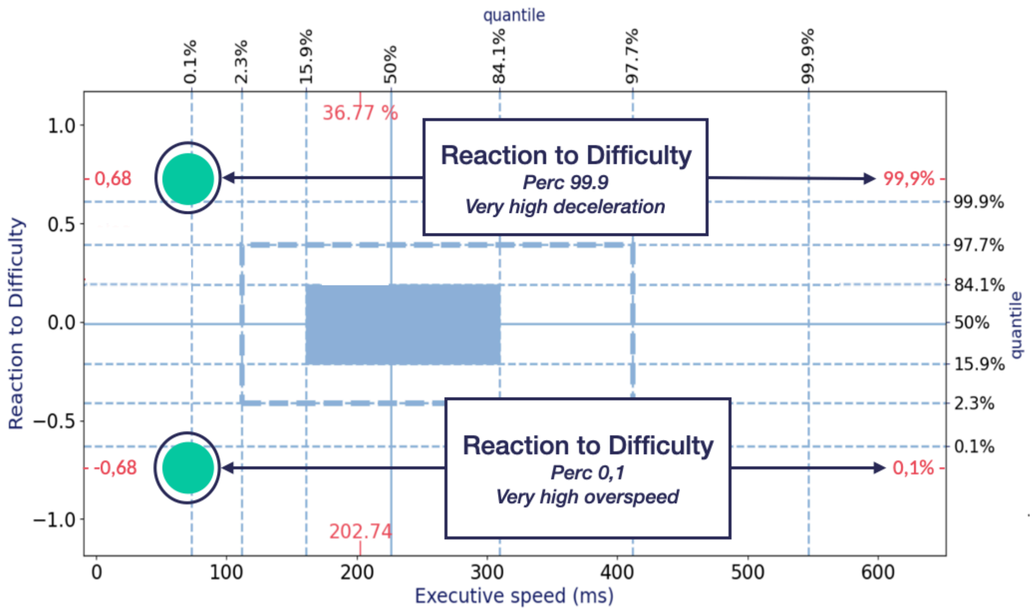


Figure 21 : Description of the areas related to reaction to difficulty

4.4. Page 3 : General results

The general results table (Figure 22) presents the four main results from the graph in numerical form, including means, confidence intervals, percentile ranks, and standard deviations. These scores are accompanied by qualitative descriptions to make the data easier to interpret. The participant's results are adjusted for age and sex and compared to norms derived from a sample of subjects aged 13 to 80 years, allowing for calculations of deviations from the mean.

1.1 MindPulse: General Results

INDEX	Average	Confidence interval 95%	Percentile rank*	STD	Descriptive
Alert / Vigilance function					
Speed: Simple Reaction Time (SRT)	*335.28*	[328.35 -- 342.91]	*67.12%*	0.44	*Average*
Orientation Function / Selective Attention					
Speed: Executive speed (ES)	202.74	[193.60 -- 211.77]	36.77%	-0.34	Average
Executive control					
Global precision: Total Errors	4	[3.00 -- 6.00]	91.10%		Medium weak
Reaction to the difficulty (RD)					
Reaction to difficulty (RD)	*0.22*	[0.17 -- 0.27]	*87.01%*	1.13	*Medium deceleration*

** The percentile rank is the percentage of individuals achieving a lower value.*

Figure 22 : General results table

The interpretation of these normative values can be facilitated with the correspondence between percentiles, qualitative descriptors, and standard deviations shown below (Figure 23), available on page 8 of the report.

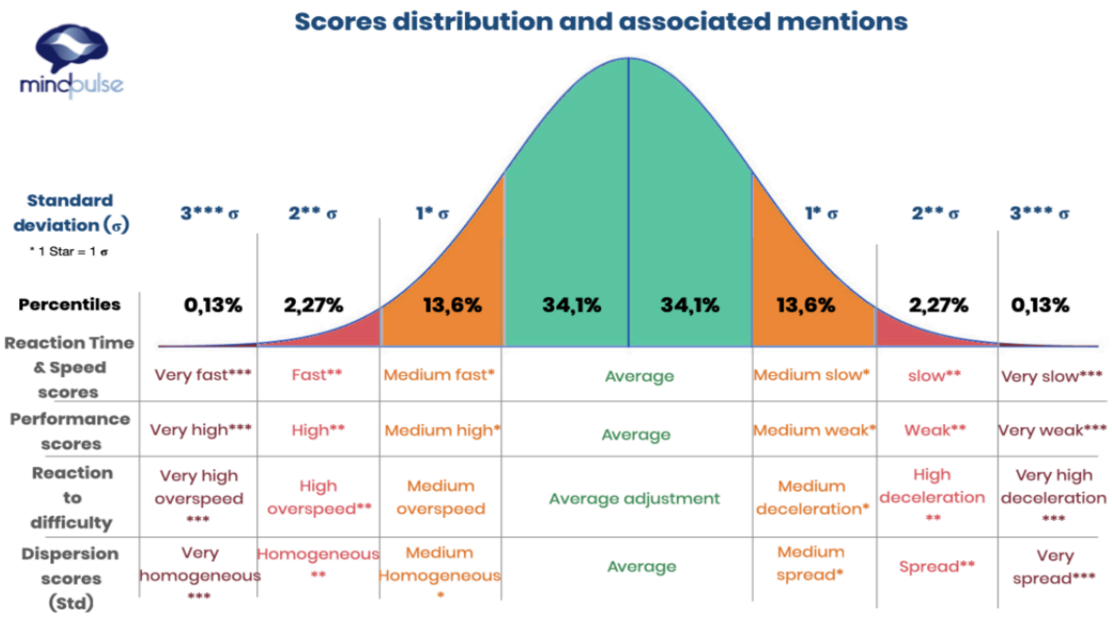


Figure 23 : Diagram of the correspondence between different normative values and their designation.

4.5. Page 3 : Reaction Times (TR) Trends in the 3 Conditions - Subject Variability

The three graphs titled "Subject's TR Trends for the 3 Conditions" (Figure 24) show the variation in Reaction Times of the subject throughout the three parts of the test, based on the time elapsed since the beginning of each test. This is a measure of attention stability. The typical variations (standard deviations) of TRs are calculated based on the subject's performance, making each subject their own control. Adjustments for age and sex are also made. The graph is smoothed to aid visualization (i.e., it is not an exact representation of each response but a "rounded" view of the test administration, using Gaussian smoothing).

2.2 Proceedings of the subject's RT for the 3 conditions

Evolution of the subject's reaction times to the 3 parts of the test and over the test unfolding (smoothed curve and RT adjusted according to age and sex). Green represents the norm +/- 1 SD; beige zones represent variations between 1 and 2 SD. White zones correspond to pathological variations beyond +/- 2 SD. Stars correspond to errors or outlier answers. A: Anticipation Error; C: Choice Error, O: Omission Error; Ab: Aberrant response. *Cf. note (3)*

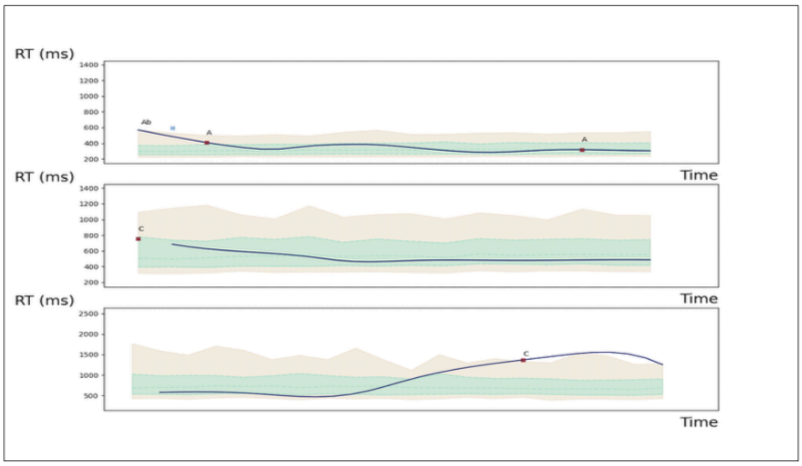


Figure 24 : Participant's RT in the 3 conditions

In each graph, the green area represents the strict normal range (<1 standard deviation, SD) around the subject, while the beige area represents the intermediate range, between 1 and <2 SD around the subject. Areas below or beyond the beige zone fall into the pathological range of more than 2 SD. When variability is high, these zones help the clinician determine whether the subject deviates from the norm only occasionally or consistently.

Each star represents an error or an aberrant response. Aberrant responses correspond to “attention lapses” or attention blackouts, constituting a TR greater than 2 SD from the subject's average. The number of aberrant responses, if any, is reported to the left of the graph. Among all subjects, aberrant responses are rare; a single aberrant response is considered normal. Two aberrant responses are considered "borderline" and raise questions about the testing conditions. From 3 aberrant responses onward, the result is considered abnormal.

4.6. Page 4 : General profile of Decision making

This section provides a qualitative summary of the subject's performance to better understand the functioning and integrity of the various cognitive sub-components of decision-making. Presented in a table (figure 25), this part also offers an interpretation of the results based on cognitive processes to facilitate the clinician's analysis and interpretation. The attentional model of Posner, which includes alerting, orienting, and executive attention functions, is integrated into this presentation.

3. GENERAL PROFILE OF DECISION-MAKING

This is the elementary level of decision making (perceptual-motor). Cf. note (4)

INDEX		Average	STD	Descriptive
Alert / Vigilance function				
Speed	Simple Reaction Time (SRT)	335.28	0.44	Average
Precision	Omission errors	0		Normal
Precision	Aberrant answers	1		Normal
Variability	Dispersion of SRT	95.53	1.73	Medium spread
Orientation Function / Selective Attention				
Speed	Executive speed (ES)	202.74	-0.34	Average
Precision	Wrong Choice Errors (C)	4		Medium weak
Variability	Dispersion of RT with categorization	286.29	1.89	Medium spread
Executive control				
Precision	Total errors	4		Medium weak
Flexibility				
Speed	Double Categorization	762.16	0.38	Average
Precision	Errors related to the introduction of a second choice (Overload).	1		Medium weak
Inhibitory control				
Speed	Go/NoGo	494.14	-0.53	Average
Precision	Inhibition errors (I)	1		Medium weak
Impulsivity				
Precision	Anticipation errors (A)	2		Weak
Reaction to the difficulty				
	Reaction to the difficulty (RD)	0.22	1.13	Medium deceleration

Figure 25 : General profile of decision making : summarize all the scores

However, this general profile cannot replace the interpretation and analysis of the clinician, who has knowledge of the subject's profile and medical history. Below are the different functions measured, which appear in this table:

- **Alerting Function**: This measures the vigilance and reactivity of attention as well as its intensity. Alerting can be assessed through the Simple Reaction Time (TRS), as well as omissions errors on TRS, TR1C, and TR2C, and through joint errors on TR2C.
- **Orienting Function**: This relates to attentional selectivity. It is measured by the Executive Speed (ES) index and by choice errors.
- **Executive Control**: The integrity of executive control is evaluated through the total number of errors and the dispersion of response times on TR1C and TR2C.
- **Flexibility**: This is assessed through the number of choice errors and overload errors.
- **Inhibitory Control**: This is evaluated notably by the number of inhibition errors and by the score on the single-choice categorization test (TR1C).
- **Impulsivity**: This is primarily measured by the number of commission errors.
- **Reaction to Difficulty (RD)**: This is directly measured by its own index.

4.7. Page 5 : Errors analysis

The participant's errors are detailed precisely in this table (figure 26). This section provides a more precise and detailed analysis of the different types of errors possible and present in the subject's performance. It summarizes each type of error, with the "margins" represented by a graduated scale, the number of errors committed, a qualitative qualification, and a definition/description of the type of error.

4. MINDPULSE: Error Analysis

Qualitative evaluation of errors according to the percentile ranks observed in the normative data. Percentile rank represents the percentage of people (normative data) making as many or fewer errors as the subject.

Type of error	Margin of error	Nb	Descriptive	Error definition
Total errors Cf. note (5)	Normal 0-2 Medium 3-5 Weak 6-10 Very weak ≥ 11	*4*	*Medium weak*	**All errors on the whole test (omission + anticipation + choice).** Too many errors should raise question about overall executive control or understanding and execution difficulty.
Anticipation errors Cf. note (7)	Normal 0 Medium 1 Weak 2-4 Very weak ≥ 5	*2*	*Weak*	**All anticipation errors on the whole test.** Definition: the subject answered before the picture appears Anticipation errors are associated with impulsivity
Omission errors on simple reaction time task Cf. note (6)	Normal 0 Anomaly ≥ 1	*0*	*Normal*	**Omission errors during the simple reaction time task** Definition: During the SRT task, the subject didn't answer after the image's apparition within 3 seconds. An omission error on SRT is associated with a vigilance problem or misunderstanding of the instructions. This kind of errors is extremely rare in normative data.
Omission errors on choices tasks	Normal 0 Anomaly ≥ 1	*0*	*Normal*	**Omission error during RT1C and RT2C tasks** During categorization tasks, the subject didn't answer when a picture meeting the given criteria appeared. These errors are associated with a vigilance problem or difficulties of categorization (executive) or understanding / memorization of instructions.
Wrong answer Cf. note (8)	Normal 0-2 Medium 3-4 Weak 5-8 Very weak ≥ 9	*4*	*Medium weak*	**Wrong answers during the task involving categorizations (RT1C and RT2C).** Definition: during categorization tasks, the subject reacted (unclicked) after a picture apparition that didn't correspond to the request. These are "active" choice errors. Wrong answers are associated with executive difficulties (flexibility).
Sub-categories of wrong answers (see condition RT2C):				
Inhibition errors	Normal 0 Medium 1 Weak 2-4 Very weak ≥ 5	*1*	*Medium weak*	**Wrong answers during the task involving 2 simultaneous categorization .** Definition: the color request of the 3rd task is opposite to that of the 2nd task. A color error in the 3rd task produces an inhibition error. The error is associated with an inhibition deficit.
Overload errors Cf. note (9)	Normal 0 Medium 1 Weak 2-3 Very weak ≥ 4	*1*	*Medium weak*	**Wrong answers due to the apparition of a second categorization during the task involving 2 simultaneous categorizations.** Definition: the subject makes a second choice of categorization (living / non-living) simultaneously with the categorization (white / gray). They make an error about this new categorization specifically. The error specific to this new categorization, is associated with an effect of cognitive overload. The Subject is overwhelmed in their cognitive process.
Joint errors	Normal 0 Weak 1 Very weak ≥ 2	*1*	*Weak*	**Total wrong answers on both categorizations simultaneously.** Definition: the subject is mistaken about both categorizations requested at the same time. This error type, if it's frequent, should raise the question of instructions understanding or of a general lack of vigilance.

Figure 26 : All Errors Table

4.8. Page 6 à 12 : Reading Notes

Pages 6 to 12 constitute the reading notes. These pages, identical and common to each MindPulse report, provide definitions of the main concepts related to MindPulse. Additionally, you will find the calculation methods for the indices, their definitions, reminders about MindPulse, types of errors, and the qualifiers and metric systems used.

5. Norms

The establishment of norms for ages 13 to 80 was made possible through collaboration between our teams and numerous clinicians throughout France. Their names can be found on our website: https://itsbrain.mindpulse.net/en/cliniciens-partenaires.

The methodology and establishment of these norms are detailed in the article published in *Applied Neuropsychology: Adult* in February 2024. The link to the article is available on our website: https://itsbrain.mindpulse.net/en/article-adult-norm/.

Here is the abstract :

Introduction: We present adult normalized data for MindPulse (MP), a new tool evaluating attentional and executive functioning (AEF) in decision-making.

Method: We recruited 722 neurotypical participants (18–80 years), with 149 retested. The MP test includes three tasks: Simple Reaction Time (SRT), Go/No-go, and complex Go/No-go, involving perceptual components, motor responses, and measurements of reaction time (RT) and correctness. We compare responses, evaluating 14 cognitive indices (including new composite indices to describe AEF: Executive Speed and Reaction to Difficulty).

Analysis: We adjust for age/sex effects, introduce a difficulty scale, and consider standard deviations, aberrant times, and Spearman Correlation for

speed-accuracy balance. Wilcoxon unpaired rank test is used to assess sex effects, and linear regression is employed to assess the age linear dependency model on the normalized database.

Results The study demonstrated age and sex effects on RTs, in all three subtests, and the ability to correct it for individual results. The test showed excellent validity (Cronbach Alpha for the three subtasks is 92, 87, 95%) and high internal consistency ($p < 0.001$ for each subtask significantly faster than the more complex subtask) of the MP across the wide age range. Results showed correlation within the three RT parts of the test ($p < .001$ for each) and the independence of SRT, RD, and ES indices. The Retest effect was lower than intersubject variance, showing consistency over time.

Discussion: This study highlights the MP test's strong validity on a homogeneous, large adult sample. It emphasizes assessing AEF and Reaction to Difficulty dynamically with high sensitivity.

Clinical Cases

A collection of clinical cases is available on our website: https://itsbrain.mindpulse.net/en/cas-clinique/ to help you become more familiar with the use and, more importantly, the interpretation of MindPulse in your practice.

You will find cases involving patients with long COVID, learning difficulties, Autism Spectrum Disorder (ASD), ADHD, and mild traumatic brain injury (MTBI). This section is regularly updated with new clinical cases encountered by our clinical experts.

Bibliographie

- **Bari, A., & Robbins, T. W. (2013).** Inhibition and impulsivity: Behavioral and neural basis of response control. *Progress in Neurobiology, 108*, 44-79. https://doi.org/10.1016/j.pneurobio.2013.06.005
- **Bechara, A., Damasio, H., Damasio, A. R., & Anderson, S. W. (1994).** Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50*(1-3), 7-15. https://doi.org/10.1016/0010-0277(94)90018-3
- **Boehm, U., Klauer, K. C., & Voss, A. (2021).** Unifying cue utilization and conflict monitoring in cognitive control processes. *Journal of Experimental Psychology: General, 150*(1), 130-148. https://doi.org/10.1037/xge0000861
- **Brenner, L. A., Breshears, R. E., & Betthauser, L. M. (2015).** Neuropsychological correlates of suicide among individuals with traumatic brain injury. *Brain Injury, 29*(1), 50-57. https://doi.org/10.3109/02699052.2014.965211
- **Chen, S. (2022).** A comprehensive review of decision-making models in mental health research. *Annual Review of Clinical Psychology, 18*, 399-422. https://doi.org/10.1146/annurev-clinpsy-080620-104752
- **de Gee, J. W., Tsetsos, K., & Donner, T. H. (2020).** Decision-related pupil dilation reflects upcoming choice and individual bias. *Proceedings of the National Academy of Sciences, 117*(28), 17032-17038. https://doi.org/10.1073/pnas.1912474117
- **Diamond, A., & Ling, D. S. (2013).** Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience, 4*, 1-20. https://doi.org/10.1016/j.dcn.2012.11.002
- **Dombrovski, A. Y., & Hallquist, M. N. (2017).** The decision neuroscience perspective on suicidal behavior: Evidence and hypotheses. *Current Opinion in Psychiatry, 30*(1), 7-12. https://doi.org/10.1097/YCO.0000000000000293
- **Evans, N. J., & Wagenmakers, E.-J. (2020).** Evidence accumulation models: Current limitations and future directions. *Psychonomic Bulletin & Review, 27*(1), 173-189. https://doi.org/10.3758/s13423-019-01605-7
- **Fabre-Thorpe M. (2011).** The characteristics and limits of rapid visual categorization. *Frontiers in psychology,* 2, 243. https://doi.org/10.3389/fpsyg.2011.00243

- **Frank, M. J., Seeberger, L. C., & O'Reilly, R. C. (2007).** By carrot or by stick: Cognitive reinforcement learning in Parkinsonism. *Science, 306*(5703), 1940-1943. https://doi.org/10.1126/science.1102941
- **Gazzaley, A., & Nobre, A. C. (2012).** Top-down modulation: Bridging selective attention and working memory. *Trends in Cognitive Sciences, 16*(2), 129-135. https://doi.org/10.1016/j.tics.2011.11.014
- **Godefroy, O., Roussel, M., Despretz, P., Quaglino, V., & Boucart, M. (2010).** The dysexecutive syndrome of Alzheimer's disease: The role of orbitofrontal cortex. *Brain, 133*(5), 1295-1306. https://doi.org/10.1093/brain/awq047
- **Hallquist, M. N., Baer, R. A., & Dombrovski, A. Y. (2018).** Hallmarks of impulsive and disinhibited behavior: Toward a quantitative psychiatry approach in borderline personality disorder. *Current Behavioral Neuroscience Reports, 5*(3), 254-263. https://doi.org/10.1007/s40473-018-0156-5
- **Huang-Pollock, C. L., Maddox, W. T., & Karalunas, S. L. (2020).** Developmental improvement in speed-accuracy trade-offs is associated with increased emphasis on accuracy. *Journal of Experimental Child Psychology, 190*, 104709. https://doi.org/10.1016/j.jecp.2019.104709
- **Lerche, V., Mertens, U. K., & Voss, A. (2020).** The speed-accuracy tradeoff effects in diffusion models depend on both the response-stimulus interval and the response mode. *Acta Psychologica, 206*, 103056. https://doi.org/10.1016/j.actpsy.2020.103056
- **Miller, E. K., & Cohen, J. D. (2001).** An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*(1), 167-202. https://doi.org/10.1146/annurev.neuro.24.1.167
- **Moustafa, A. A., Sherman, S. J., & Frank, M. J. (2008).** A dopaminergic basis for working memory, learning, and attentional shifting in Parkinsonism. *Neuropsychologia, 46*(13), 3144-3156. https://doi.org/10.1016/j.neuropsychologia.2008.07.011
- **Myers, N. E., Visscher, K. M., & De Lange, F. P. (2022).** Dynamic adjustments of decision thresholds in human visual cortex. *Nature Neuroscience, 25*(1), 123-130. https://doi.org/10.1038/s41593-021-00948-7
- **Pitliya, P., Subramaniam, K., & Vinogradov, S. (2022).** Depressive symptoms in schizophrenia: Relationship with the prefrontal cortex and treatment implications. *Schizophrenia Research, 239*, 102-110. https://doi.org/10.1016/j.schres.2021.11.009

- **Ratcliff, R., & McKoon, G. (2008).** The diffusion decision model: Theory and data for two-choice decision tasks. *Neural Computation, 20*(4), 873-922. https://doi.org/10.1162/neco.2008.20.4.873
- **Ratcliff, R., & Van Dongen, H. P. A. (2011).** Diffusion model for one-choice reaction-time tasks and the cognitive effects of sleep deprivation. *Proceedings of the National Academy of Sciences, 108*(27), 11285-11290. https://doi.org/10.1073/pnas.1100483108
- **Roussel, M., & Godefroy, O. (2019).** The assessment of the dysexecutive syndrome in Alzheimer's disease: A novel tool. *Frontiers in Aging Neuroscience, 11*, 329. https://doi.org/10.3389/fnagi.2019.00329
- **Thorpe, S. J., & Fabre-Thorpe, M. (2001)**. Neuroscience. Seeking categories in the brain. *Science* (New York, N.Y.), 291(5502), 260–263. https://doi.org/10.1126/science.1058249
- **Vidal, L., Bourdin, B., Marqueste, T., & Lévêque, C. (2020).** Cortical processing of fatigue perception in patients with multiple sclerosis: A neurophysiological study. *Journal of Neurology, 267*(4), 1049-1058. https://doi.org/10.1007/s00415-019-09679-8
- **Voss, A., & Voss, J. (2008).** A fast numerical algorithm for the estimation of diffusion model parameters. *Journal of Mathematical Psychology, 52*(1), 1-9. https://doi.org/10.1016/j.jmp.2007.09.005
- **Voss, A., & Voss, J. (2007).** Fast-dm: A free program for efficient diffusion model analysis. *Behavior Research Methods, 39*(4), 767-775. https://doi.org/10.3758/BF03192967
- **Voss, A., Rothermund, K., & Voss, J. (2004).** Interpreting the parameters of the diffusion model: An empirical validation. *Memory & Cognition, 32*(7), 1206-1220. https://doi.org/10.3758/BF03196893
- **Van Zomeren, A. H., & Brouwer, W. H. (1994).** *Clinical neuropsychology of attention*. Oxford University Press.

Annexes

1. User Guide

These guides, specially designed to be printable, serve as a summary resource to facilitate the use of the tool and ensure proper testing conditions.

2. Help with the report

To make it easier to read the results, qualitative descriptors are used in each summary table and for each parameter assessed. These are intended to quickly and clearly inform the clinician about the qualitative level of the subject's performance according to our norms. However, it is important to note that these descriptors do not replace a clinical evaluation of the individual and are not intended to substitute for the clinician's interpretation.

Below is a table summarizing the possible qualitative terms according to the variables studied/measured, providing a quick description/definition in more detail.

Table 1 : Summary of Terms Used in the Report

Variables	Qualification	Definition
Speed & Performances Scores	**Very Fast / High**	The subject exhibits a very fast reaction time or a performance significantly above the average for their age group.
	Fast / High	The subject exhibits a fast reaction time or a performance above the average for their age group.

	Moyenne Rapide / Elevée	The subject demonstrates a high performance or reaction time in the upper average range for their age group.
	Average	The subject exhibits a median reaction time or average performance for their age group.
	Medium slow / weak	The subject shows a reaction time or performance in the lower average range for their age group.
	Slow / weak	The subject displays a slow reaction time or performance below the average for their age group.
	Very Slow / Weak	The subject presents a very slow reaction time or performance significantly below the average for their age group.
Reaction to Difficulty	**Very Overspeed**	The subject exhibits a (very) high level of speeding in response to difficulty for their age group. The speed of response to increased difficulty is (very) rapid.
	Medium Overspeed	The subject shows an average level of speeding in response to difficulty for their age group. The speed of response to increased difficulty is slightly elevated.

	Average Adjustement	The subject demonstrates a normal amount of extra time in response to difficulty.
	Medium Deceleration	The subject shows moderate slowing in response to difficulty for their age group. They slow down slightly to adjust to the difficulty of the task.
	High Deceleration	The subject exhibits (very) significant slowing in response to difficulty for their age group. They slow down considerably to adjust to the difficulty of the task.
Variability	**Very Homogeneous**	The subject displays very stable performance over time, with minimal variability in reaction times relative to their age group.
	Homogeneous	The subject shows stable performance over time, with low variability in reaction times relative to their age group.
	Medium homogeneous	The subject demonstrates slightly more stable performance than average over time, with low variability in reaction times relative to their age group.
	Medium	The subject's performance in terms of stability over time is appropriate for their age group.
	Medium Spread	The subject exhibits slightly less stable (more dispersed) performance over time, with somewhat excessive

		variability in reaction times relative to their age group.
	Spread	The subject shows unstable (dispersed) performance over time, with too much variability in reaction times relative to their age group.
	Very Spread	The subject demonstrates very unstable (highly dispersed) performance over time, with a lot of variability in reaction times relative to their age group.
Errors	**Normal**	The subject produces a normal number of errors relative to the average for their age group.
	Medium Weak	The subject produces a borderline number of errors relative to the average for their age group.
	Weak	The subject produces too many errors relative to the average for their age group. Their accuracy is low.
	Very Weak	The subject produces a very high number of errors relative to the average for their age group. Their accuracy is very low.