III–3.2.6.4
Sustained Attention to Response Task (SART)
– a measure of daytime vigilance

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CONCLUSION
The SART is a computerized, cheap, and easy to administer sustained attention task for the quantification of vigilance consisting of two to five 4-minute 19-second lasting test sessions. The SART error count is a validated quantifier of vigilance and treatment effect in patients with central hypersomnias, including narcolepsy. The predictive value of the SART for accident risk and driving safety remains to be investigated.

INTRODUCTION
Diagnostic tests in sleep medicine have traditionally focused on the self-reported or objectively measured tendency to fall asleep, or the ability to resist sleepiness. Another important and increasingly recognized problem in patients with excessive daytime sleepiness is that most of them are suffering from an impaired vigilance during wake. In contrast to sleepy people, fully awake people are expected to be aware of potential changes in their environment. This capability, called vigilance (LIM and DINGES 2008), is a fundamental prerequisite for attention and, as such, for higher cognitive functions required in daily life, for instance at school or work. Although many authors have used the terms vigilance and sustained attention interchangeably, they are not synonyms. Rather, sustained attention represents an executive function that can be regarded as an operationalization of vigilance. Several methods are available for the measurement of vigilance. An ideal test provides an objective quantification of the level of vigilance and is easy to administer and perform. These practical requirements are best met by response tasks assessing sustained attention. This chapter focuses on a vigilance test that has been reasonably well validated in central hypersomnias, the Sustained Attention to Response Task (SART).

SUSTAINED ATTENTION TO RESPONSE TASK (SART)
The SART concerns a computerized task consisting of at least two sessions of 4:19 minutes each, during which subjects should withhold presses to one out of nine stimuli (ROBERTSON et al. 1997). In other words, it is a so-called go/no-go task in which the no-go target appears unpredictably and rarely, and in which both accuracy, assessed through commission and omission errors, and response speed, quantified as reaction time (RT), are important. The test has originally been developed for patients with traumatic brain injury (ROBERTSON et al. 1997), but demonstrated to be able to quantify vigilance impairment in patients suffering from central hypersomnias including narcolepsy (FRONCZEK et al. 2006, VAN SCHIE et al 2012).

Clinical protocol
Subjects are seated on a chair in front of a computer screen in a dimly lit room. The numbers 1 to 9 are displayed 25 times (225 numbers in all) in random order on a black computer screen. Subjects have to respond to the appearance of each number by pressing a button, except when the number is a 3, which occurs 25 times in all. The button has to be pressed

before the next number appears. Protocols differ in the instruction provided to subjects: some instruct to give equal importance to accuracy and speed in performing the task, others to prefer accuracy to speed. The latter has been demonstrated to be most discriminative for differences between narcolepsy patients and healthy individuals. This is due to lower within-group performance differences in healthy individuals by diminishing the so-called 'speed-accuracy trade-off' (VAN SCHIE et al. 2014). At least two SART sessions with a 1.0-hour break in between are required for a reliable measurement, preceded by a full training session to eliminate or reduce a repetition effect. The primary outcome measure is the error count, consisting of key presses when no key should be pressed (i.e. commission errors), and absent presses when a key should have been pressed (i.e. omission errors). For a detailed description see table 1.

Normative data

There is no large systematically collected set of normative data for the SART. A complicating factor is that different instructions were used. Normative data based on a small study are only available for the instruction to prefer accuracy to speed in a 5-sessions protocol (FRONCZEK et al. 2006): the median SART error score was 10.6 (25^{th} – 75^{th} percentile 6.1-18.7) errors for narcolepsy patients and 2.0 (25^{th} – 75^{th} percentile 1.3-4.0) errors for controls. Based on the 95^{th} percentile in controls (5.4 errors), a 5-error cutoff point was proposed. There is no direct comparison between patients and controls for the instruction to pay equal importance to accuracy and speed. Data of the capability of the SART to measure treatment effect in narcolepsy are available for the instruction to pay equal importance to accuracy and speed: an average improvement of 1.2 errors was detected after treatment with modafinil, 2.5 errors after treatment with pitolisant, 0.7 after treatment with sodium oxybate and no improvement was observed in a placebo group (0.1errors) (DAUVILLIERS et al 2013, VAN SCHIE et al. in review). [7]

Validation

To date, the validation of the SART as a tool to measure sustained attention in sleep-disordered patients is based on a comparison of SART results between patients with narcolepsy and healthy controls, which indicated good construct validity. Simultaneously, no correlations were found between SART performance and subjective sleepiness (ESS) or between SART performance and the average sleep onset latency during the Multiple Sleep Latency Test (MSLT), showing discriminant validity with these measures of sleepiness (FRONCZEK et al. 2006). Moreover, the SART has been demonstrated capable of measuring treatment effects (see above). A study in healthy individuals indicated that time of day (morning versus afternoon) did not influence SART performance, nor did napping in between sessions when the SART is administered 1.0 hour after the nap (as in an MSLT design) (VAN SCHIE et al. 2014). However, these findings have not yet been replicated in patients with hypersomnia. The major limitation of the SART is that a poor performance does not necessarily correspond to a vigilance problem, but may also be attributed to the inability to focus attention without being diverted to concurrent, possibly relevant stimuli, or to respond in a timely manner.

Place of the SART in practice

Accordingly, the importance of the SART does not lie in the diagnostic aspect of performance impairment, but in the quantification of such impairment and its comparison between

different situations, such as before and on treatment. It is applied to quantify vigilance similarly as the Maintenance of Wakefulness Test (MWT) is applied to quantify sleepiness. Both tests can be combined in a one-day protocol. A recent study compared improvements in SART, MWT, and Epworth Sleepiness Scale (ESS) performance in narcolepsy patients before and after stimulant treatment to the subjective rating of improvement by patients themselves (VAN DER HEIDE et al 2015). This study demonstrated that the SART correlated better to the degree of improvement experienced by narcolepsy patients than the MWT, and almost as well as the ESS did. The authors therefore concluded that a combination of the SART and ESS comprised a more comprehensive, valid evaluation of treatment effects in narcolepsy, with the ESS representing a subjective estimate of how sleepy patients felt, and the SART as an objective measurement of vigilance. Moreover, this combination has the advantage of not requiring much time or money, while the complexity and costs constitute major drawbacks of the MWT. As with sleep latency measurements, performance on the SART is presumably influenced by motivational and environmental factors. The SART is susceptible to voluntary efforts to perform poorly. For matters such as driving, performing better than usual is often wanted. The SART is quite robust against attempts in that direction though, in contrast to the MWT, in which patients can use tricks to stay awake. Hence, the SART is suitable in situations where patients have a vested interest in performing well. However, no scientific data have yet been available to answer the question whether the SART is a more reliable estimator of the risk of accident in the real-world situation than the MWT.

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Availability of the Sustained Attention to Response Task
The SART program may be obtained free of charge from the corresponding author (e-mail *m.k.m.van_schie@lumc.nl*) if the recipient agrees to utilize the program for non-commercial purposes only, i.e. for scientific or clinical purposes.

Table 1
Recommendations for the SART protocol

1. The 5-trial protocol prior to each of 5 MSLT sessions is recommended to quantify the level of vigilance in the diagnostic phase.

2. In any other phase, it is recommended to administer at least 2 SART sessions with 1.0-1.5 hour in between, preceded by a full training session.

3. The use of tobacco, caffeine and other medications by the patient before and during the SART should be addressed and decided upon by the sleep clinician before SART.

4. Subjects are seated on a chair in front of a computer screen in a dimly lit room.

5. The font size is chosen at random from 26, 28, 36, or 72 points. The numbers are presented in a predetermined and quasirandom way so that identical numbers are not clustered. Each number is presented for 250 milliseconds, followed by a blank screen for 900 milliseconds.

6. Instructions to the patient consist of the following: “A number from 1 to 9 will be shown 225 times in random order. You have to respond to the appearance of each number by pressing a button, except when the number is a 3. You have to press the button before the next number appears, but note that accuracy is more important than speed.”

7. The following data should be recorded: the number of times a key was pressed when a 3 was presented (commission errors), the times when no key was pressed when it should have been (omission errors), and the reaction time of every correct press.

8. The SART error score consists of the total number of errors, expressed as the sum of the commission and omission errors.

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