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Monitoring Cognitive and Emotional Processes Through Pupil and Cardiac Response During Dynamic Versus Logical Task

Mickaël Causse · Jean-Michel Sénard ·
Jean François Démonet · Josette Pastor

Abstract The paper deals with the links between physiological measurements and cognitive and emotional functioning. As long as the operator is a key agent in charge of complex systems, the definition of metrics able to predict his performance is a great challenge. The measurement of the physiological state is a very promising way but a very acute comprehension is required; in particular few studies compare autonomous nervous system reactivity according to specific cognitive processes during task performance and task related psychological stress is often ignored. We compared physiological parameters recorded on 24 healthy subjects facing two neuropsychological tasks: a dynamic task that require problem solving in a world that continually evolves over time and a logical task representative of cognitive processes performed by operators facing everyday problem solving. Results showed that the mean pupil diameter change was higher during the dynamic task; conversely, the heart rate was more elevated during the logical task. Finally, the systolic blood pressure seemed to be strongly sensitive to psychological stress. A better taking into account of the precise influence of a given cognitive activity and both workload and related task-induced psychological stress during task performance is a promising way to better monitor operators in complex working situations to detect mental overload or pejorative stress factor of error.

M. Causse (✉) · J. F. Démonet · J. Pastor
INSERM, U825, Pavillon Riser, CHU Purpan,
31000 Toulouse, France
e-mail: mickael.causse@inserm.fr

M. Causse · J. F. Démonet · J. Pastor
University Toulouse III Paul Sabatier, 31000 Toulouse, France

Present Address:
M. Causse
ISAE, Toulouse, France

J.-M. Sénard
INSERM, U858, CHU Rangueil, 31400 Toulouse, France

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Introduction

The definition of metrics able to predict the performance of an operator is a great challenge. In mental workload literature (Brookings et al. 1996; Dahlstrom and Nahlinder 2006), as well as in human machine interface studies (Gevins and Smith 2003; Iqbal et al. 2005; Lemmens et al. 2007), psychophysiological data are commonly used as an index of the level of cognitive demand generated by a task (e.g. increased temporal demand, memory loading etc.). This level is characterized by physiological changes, in particular the catabolic activity within the autonomous nervous system (ANS), that have been associated with energy mobilization and the investment of mental effort to deal with the task (Fairclough et al. 2005; Gaillard 2001). Two physiological parameters are classically recorded: the electrocardiogram (ECG) and the tonic or phasic pupil response, in particular the pupil diameter (PD) change. The ECG has proved to be a reliable measure of task demand fluctuations, for instance, an increased task difficulty (e.g. difficulty of a mental arithmetic task) is associated with an increased heart rate and/or blood pressure (Boutcher and Boutcher 2006; Sosnowski et al. 2004). In addition, the pupil size has also been shown to reflect processing load or mental effort (Moresi et al. 2008; Recarte and Nunes

2003). In parallel, emotion (including psychological stress) is also well-known to impact the ANS. Light and Obrist (1980) showed that cardiovascular response to an easy version of a reaction time task with a monetary reward was similar to the response to a more difficult version without monetary incentive. More recent studies found that the heart rate (HR) increased during positive and negative affect (Brosschot and Thayer 2003; Warner and Strowman 1995) and that PD was larger after visual (Bradley et al. 2008; Causse et al. 2007) or auditory (Partala and Surakka 2003) emotional stimulation. These results show that HR can be both influenced by workload and emotion/arousal.

As noticed by Vo et al. (2008), whereas a substantial literature focuses on cognitive or emotional effect on ANS, little studies take into account their interactions. In focusing on workload effect, potential task related psychological stress is ignored and its role in performance degradation is neglected. Studies often interpret ANS variations as a linearly and unilateral consequence of an increased mental effort, yet, cognitive activity can modulate emotional state (Hariri et al. 2003) and on the other hand, emotional factors can modulate cognitive performance (Houdé et al. 2000).

Parasuraman and Hancock (2001) hypothesized that mental workload may be driven by the load that the task imposes on human operators but that it is not deterministic, because workload is also mediated by the individual response, depending of skill levels, task management strategies, and other personal characteristics. This fact was already suggested by Light and Obrist (1983), who showed the effect of task difficulty and performance feedback on cardiovascular response, but outlined that tasks requiring "active" vs. "passive" coping implied different autonomic patterns (Obrist et al. 1978). In this way, the nature of the cognitive processes or the type of responses involved in a task could play a major role on the ANS activity.

The complex relationship between the ANS and the cognition may find, at least in part, a convincing neurological explanation in the cross-influences between the dorsolateral prefrontal cortex (DLPC), a major substratum of the executive functions (EF), which refer to the processes that underlie flexible goal-directed behaviour, e.g. dominant responses inhibiting, goal creating and maintaining, action sequencing, decision-making (Burgess et al. 1998), and the medial (in particular ventral) prefrontal cortex (MPFC), associated with "emotional processes" (Bechara et al. 1995; Heberlein et al. 2008). Indeed, Simpson et al. (2001b) showed in a PET scan experiment that the achievement of an executive task provoked anxiety and that skill acquisition by practicing verb generation improved performance. These observations were strongly correlated with blood flow reductions in MPFC and hypothalamus. A separate behavioral study indicated that anxiety, measured by heart rate and self-reports, was high during naïve task performance and decreased with practice. These results suggest that the MPFC is part of a network including the hypothalamus and brainstem, the activity of which reflects a dynamic interplay between cognitive task performance and emotion. However, the direct relationship between heart rate reduction and the improvement of performance could be incomplete; an additional effect may contribute to heart rate reduction: a non task-specific psychological stress, high during task discovery, and reducing progressively with task habituation. In this perspective, the ANS arousal is not necessary only linked to the mental load and task performances increasing. To investigate this assertion, a task performed by non expert and within which the performance could not be increased is required.

Another interrogation is the interpretation of ANS response according to the performed task. Some authors highlight the fact that ANS activity could be linked to the specific cognitive processes generated by a given task. Distinct brain mechanisms seem to subserve different forms of arousal and there are selective co-occurrences of brain areas' activations and evoked ANS responses' magnitude (Critchley et al. 2005). For instance, the task difficulty has been found to activate the anterior cingulate cortex (Paus et al. 1998) and different ANS patterns are found in an attentional vs. a planning task (Middleton et al. 2001). According to Morrison (2001), the sympathetic outflows to different targets can be differentially affected by central stimulation, during reflex and behavioral responses, in a much more complex way than a monolithic activation reflecting and increased arousal in sympathetic activation that were the focus of early investigators.

Our first goal is to get a better insight of the ANS activity during two different types of tasks focusing on reasoning and executive functioning: logical reasoning, which is the core of high-level cognition, and reasoning in dynamic situations, which is closer to real-life situations and involves fluid reasoning (Kalbfleisch et al. 2007). These cognitive processes are very common in everyday human activity and also in working situations, the dynamic task requires problem solving in a world that continually evolves over time (e.g. dynamic control of power plants), the deductive reasoning and the verbal working memory load that it involves is very representative of problem solving processes performed by operators facing everyday working issues.

The second goal is to disentangle, from the mental load effect of the tasks, the psychological stress effect due to task novelty, respectively on PD, systolic blood pressure (SBP) and HR. This disentangling is possible thanks to the deductive task, where no learning effects should occur and where the mental load is stable.

On the above basis, our work relies on three hypotheses. The first one is that, since difficulty raises from time pressure in the early stage of the dynamic task and from the non-ecological and difficult aspect of deductive reasoning in non-experts in the logical task, the two tasks may have specific time-course effects on the sympathetic cardiovascular arousal. The second one is that the tasks, which involve different processes, such as visual attention in the dynamic task and verbal working memory in the deductive logical task, may evoke different ANS response patterns. The last hypothesis is that a non task-specific psychological stress is generated by the task novelty and thus that the deductive logical task, should also generate a time-course effect in spite of the fact that no learning should occur and that the mental load is considered as constant.

Method

Participants

Healthy participants ($n = 24$) were recruited by local advertisement. Inclusion criteria were: young (age: 27.3 ± 3.69), male, native French speakers, right-handed, under or postgraduate. Non-inclusion criteria were expertise in logics, sensorial deficits, neurological, psychiatric or emotional disorders and/or being under the influence of any substance capable of affecting the central nervous system. Inclusion and non-inclusion criteria were checked before experiment, through individual interviews with the participants. All subjects received complete information on the study's goal and experimental conditions and gave their informed consent.

Computerized Experimental Tasks

We used two main reasoning tasks involving different cognitive processes and a control task aiming at checking the participants' basic visuomotor abilities. The participants did not perform a training session before any task to keep them naive toward the task, because previous learning effect on physiological data had to be avoided (Fairclough et al. 2005). The display luminosity and the background colors were absolutely equivalent in the two tasks to control light effects on pupil response. This issue has a great importance given that we compared PD changes obtained on both tasks.

The dynamic reasoning task (Pastor et al. 1998) assesses reasoning under temporal pressure and involves executive functions like planning or self-monitoring, as well as a high visual attention. The objective is to control a network of tanks and pipes (Fig. 1) where water flows by gravity, according to the laws of hydraulics. The capacities of the top and bottom tanks are equal to the total amount of water running in the network. At the beginning of the task, all tanks, except the top one, are empty. The given instruction is "to fill the bottom tank as quick as possible by acting on on/off valves and avoid as much as possible overflowing the intermediate tanks". The workload is evolving all along this task because it is directly linked to the time pressure exerted by the flow rate in the pipes and the number of actions required to manage the flow. The first third of the task, where the comprehension of the physical property of the water flowing and the learning of the micro-world management occur, is the most difficult. This is worsened by the fact that the micro-world is designed so as to present an overflow threat at the very beginning of the test. The dynamic task is constituted of two parts, one in the left and the other in the right part of the screen. The performance feedback was permanently displayed through the water levels in the tanks and the water color changes during overflowing. The performance was measured by the percentage of water loss, the task duration and the number of actions on valves.

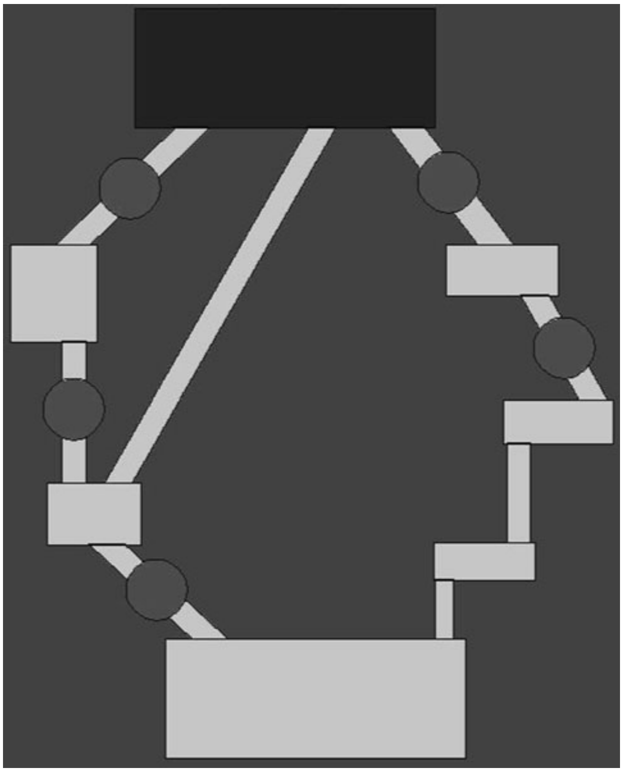
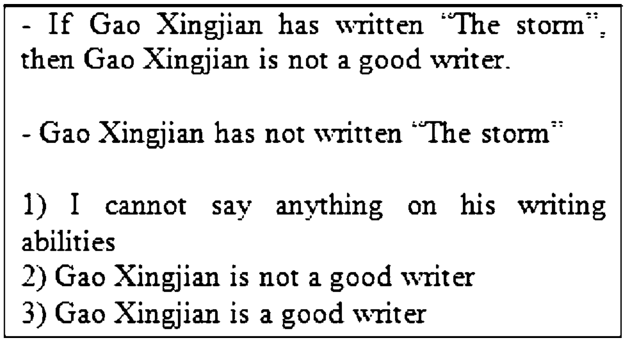


Fig. 1 The dynamic task

The second task is inspired form Natsopoulos et al. (1997). This task involves logical reasoning and is highly demanding in verbal working memory. The goal of the task is to solve syllogisms by choosing, among three suggested solutions, the one that allows concluding logically. Syllogisms (Fig. 2) are based on a logical argument in which one proposition (the conclusion) is inferred from a rule and another proposition (the premise). We used the four



- If Gao Xingjian has written "The storm", then Gao Xingjian is not a good writer.

- Gao Xingjian has not written "The storm"

1) I cannot say anything on his writing abilities
2) Gao Xingjian is not a good writer
3) Gao Xingjian is a good writer

Fig. 2 English translation of a syllogism example

existing forms of syllogisms: "modus ponendo ponens", "modus tollendo tollens", "setting the consequent to true" and "denying the antecedent". Each participant had to solve 24 randomly displayed syllogisms. The cognitive demand should not evolve with time because of the randomization of the stimuli and also because no progressive learning is supposed to occur. Indeed, we have selected subjects that did not study logic at school and according to Braine (1990), there is a universal human logic or "natural logic" defined as a set of very simple automated inference rules that are considered universal and independent of the education level, but education is required for a secondary level of reasoning that requires complex analytical reasoning abilities. The measurements were the percentage of correct answers and mean reaction times.

The target-hitting task assesses psychomotor skills. The subjects had to click as quickly as possible on a target that appeared successively at random positions on the screen. The measurement was a velocity index. This task was only intended to check the visuomotor abilities of the subjects.

Psychophysiological Measures

Subjects were tested in a moderately lit room, in which the illumination was held constant (background luminance: about 450 lux). A headphone was placed on their ears for a better isolation from disturbing noises. Participants were comfortably installed and were asked to relax and keep silent during at last 10 min so that the physiological parameters came back to a rest state characterized by a stable ECG. The PD evolves with less latency than the cardiac parameter. For instance, Hess and Polt (1964) found an increase of the pupil size during mental calculation and an immediate decrease after the answer was given. On the contrary, the heart rate may take up to a minute to come to baseline after an auditive stimulation (Vila et al. 2007). On this basis, the rest state criterion was the heart rate, the longest to come back to baseline. Cardiac and pupillometric measurements were started at the launching time of the first task. Pupillary tonic response was collected thanks to the iView X RED eyetracker (©SensoMotoric Instruments, Teltow, Germany). The analog output was digitized at 50 hz (one sampling every 20 ms). The main interest of this type of oculometer (a motorized remote camera) is that it is non-invasive, which allows a relatively ecological situation. The system compensates for head movement by tracking the corneal reflex. Both axes of the pupil ellipse are measured by the system. In the following, PD will designate the length of the horizontal axis. The cardiac parameters were recorded with a Finapress sensor plugged to an ECG (©Ohmeda 2300). The Finapress is a non-invasive continuous blood pressure monitor, based on the vascular unloading technique. The Finapress sensor was placed on the middle finger of the left hand and recorded the heart rate and the systolic blood pressure (the diastolic blood pressure was not collected). All physiological measurements were synchronized with the tasks thanks to triggers. In practice, establishing mean physiological values for a group of subjects for an entire task is meaningless because of inter-individual variability; so we used delta values (difference between working and resting states) for measuring the ANS. The baseline was subtracted to the average ANS activity during the different periods of interest.

Procedure

All the participants carried out the two different tasks. They were separated in two groups: 12 subjects performed the logical task first, and the other 12 performed firstly the dynamic one to avoid order effects. The total experimentation, including sensor placement, verification of the signal quality, consign delivery, the tasks' performance and the delays between the tasks, lasted approximately half an hour. The typical duration to perform the logical task was about 6.5 and 4.5 min for the dynamic task. The target hitting task performance lasted about 1 min. The experimentation took place in a calm office within the Centre for Clinical Investigation (Toulouse, France). Each subject specified his age, laterality and confirmed the absence of medication or other disorders. The neuropsychological tests battery was then administered.

Statistical Analysis

The pupil and cardiac individual data were filtered to eliminate artifacts. The baseline was defined on a 10 s sample before the beginning of the task. The delta values were defined as the difference between measured and baseline data.

One-way ANOVAs were used to check group effects on neuropsychological performances. Repeated measures ANOVAs were applied to analyze the evolution of the

Table 1 Average value and standard deviation using psychophysiological variables according to the 3 epochs (task time-courses) within the dynamic and the deductive task ($N = 23$)

Predictors	Mean change T1	Mean change T2	Mean change T3
Dynamic task			
Heart rate (bpm)	6.08 (±4.84)	2.35 (±2.60)	3.77 (±2.13)
Blood pressure (mmhg)	6.37 (±12.79)	4.07 (±12.16)	0.82 (±11.60)
Pupillary response (mm)	0.56 (±0.85)	0.61 (±0.65)	0.48 (±0.71)
Deductive task			
Heart rate (bpm)	6.16 (±3.83)	5.38 (±2.67)	5.63 (±2.61)
Blood pressure (mmhg)	14.46 (±19.01)	12.09 (±20.20)	10.83 (±20.46)
Pupillary response (mm)	0.38 (±0.64)	0.32 (±0.66)	0.26 (±0.74)

Only the systolic blood pressure was collected and the pupillary response reflects the horizontal diameter change

Table 2 Main ANOVA results using psychophysiological variables to predict mean changes between logical and dynamic tasks (task), task courses and cross effects of task and time (task × time) ($N = 23$)

Predictors	Task	Time course	Task × task course
Heart rate (bpm)	$p = 0.004$** $F(1.22) = 10.98$	$p = 0.001$** $F(2.44) = 7.28$	$p = 0.011$* $F(2.44) = 5.39$
Blood pressure (mmhg)	$p = 0.019$* $F(1.22) = 6.91$	$p = 0.016$* $F(2.44) = 4.24$	$p = 0.521$ $F(2.44) = 0.61$
Pupillary response (mm)	$p = 0.014$* $F(1.23) = 9.01$	$p = 0.305$ $F(2.46) = 2.42$	$p = 0.708$ $F(2.46) = 0.28$

*$p \leq 0.05$; ** $p \leq 0.01$

performances and the ANS activity within each task during the three periods (Table 1). Repeated measures ANOVAs were also used to test the task and time course effects, and their interactions, on the ANS (Table 2). Tukey's HSD post-hoc test was used to perform paired comparisons. All analyses were done with Statistica 7.1 (©StatSoft). Since the durations of the two tasks are different and dependent on the velocity of the subject, the task timeline is converted in three periods for each subject: beginning, middle and ending of the task. Behavioral and ANS results, represented by their mean values on each period, are analyzed through the three periods.

Results

Since numerous artifacts occurred, the cardiac measurements of one subject were not analyzed in the logical group; therefore data were available from only 23 subjects.

Group Comparisons

The two experimental groups were homogeneous, no differences were found on performance variables of the neuropsychological tasks, neither on ANS activity during task performance. The dynamic task performance has normative values (unpublished data) and all participants' performance fell within the normative limits. Since no normative values existed for the deductive task we checked that the participants understood well the instruction and were compliant.

Performance Evolution During the Dynamic Task

A repeated measures ANOVA (Fig. 3) showed a fall of performed actions on valves along the dynamic task ($p < 0.001$). Tukey (HSD) post-hoc tests revealed a large significant difference between the first and the third period and between the second and the third period (p's < 0.001).

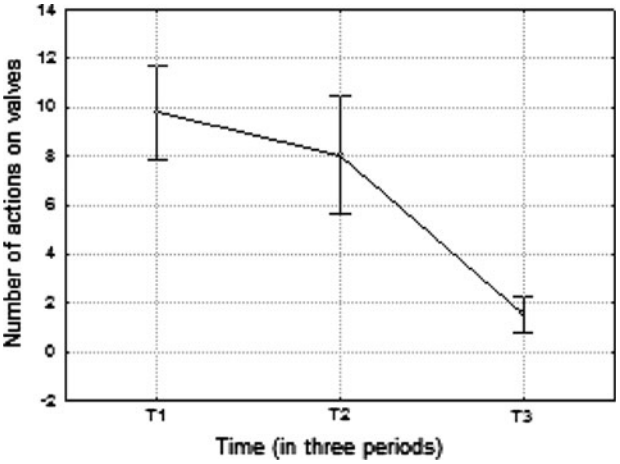


Fig. 3 Evolution of the mean number of actions on on/off valves required to manage the flow of water along the dynamic task for both groups ($N = 23$)

Performance Evolution During the Logical Task

The percentage of correct answers remained low and constant ($p = 0.641$). Only reaction times were evolving during the three periods, with a reduction of correct response times ($p < 0.001$). Tukey (HSD) post-hoc tests showed response time differences between the first and the third period and between the second and the third one (p's < 0.001).

ANS Activity: Task Comparisons and Pupillary Tonic Response

The tonic PD change was higher during dynamic task compared to the logical one ($p = 0.014$).

ANS Activity: Task Comparisons and Cardiac Parameters

A significant effect of the logical task versus the dynamic one ($p = 0.024$) was observed on the mean delta systolic blood pressure response during the whole task. The dynamic task generated a lower elevation of the systolic pressure.

A significant effect of the logical task versus dynamic one ($p = 0.002$) was also observed on the mean delta heart rate change.

ANS Activity: Time Course Effect and Tonic Pupillary Response

Pupillary tonic response remained stable along both tasks, no time-course effect was found.

ANS Activity: Time Course Effect and Tonic Cardiac Response

A global time effect was found on the heart rate for both tasks ($p = 0.001$). The paired effects showed a global time effect on T1 < T2 ($p = 0.001$) and T1 < T3 ($p = 0.01$).

An interaction between task and time course effects was also found (Figs. 4, 5), the time course was significantly different between the two tasks ($p < 0.01$). Tuckey's HSD post hoc analysis showed significant difference for T2 dynamic task <T2 deductive task ($p < 0.001$), corresponding to the epochs where the number of actions on valves is dropping in the dynamic task.

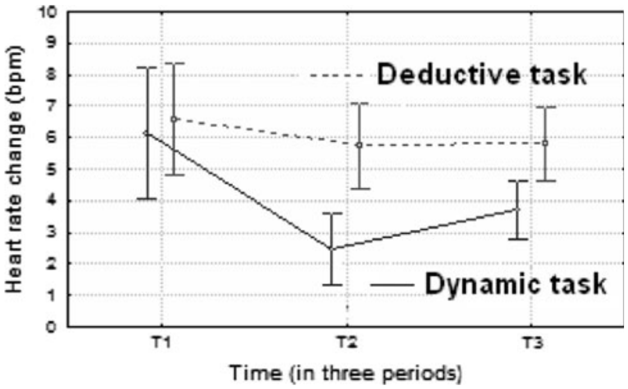


Fig. 4 Mean heart rate change during dynamic and logical task for both groups ($N = 23$)

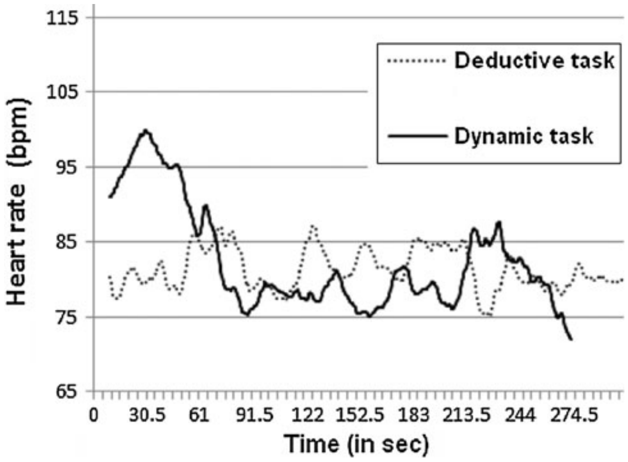


Fig. 5 Example of mean heart rate change during both dynamic and deductive tasks for one subject. The heart rate is temporarily increased during the first phase of the dynamic task, where numerous actions are required to manage the flow and temporal pressure is high. The heart rate during the deductive task remains quite stable

Discussion

Task Difficulty

The difficulty was considered to be specific to each task. As expected in the deductive task, the percentage of "irrational" behaviors remained important, with an average of more than 25% erroneous answers. Moreover behavioral data confirmed that no learning occurred during the time-course; indeed no significant improvement of the percentage of good answers occurred among the three periods of time. These results, in agreement with other reports (Braine 1990; Evans 1998), confirmed the fact that normal adults do not spontaneously apply the principles of logics and allow us to state that the difficulty of the deductive task remained high and stable all along the task achievement. The fact that the performance did not improve during its course is in favor of a sustained cognitive effort all along the task. The difficulty of the dynamic task was theoretically focused on the first period in which the subject had to manage quickly the flow of water. Indeed, according to the physical laws, the water flowing rate is slowing progressively while the amount of water in the upper tank is reducing, thus subjects had more and more time to manage the flow through on/off valves.

Task Specificity and ANS

The higher mean PD change was observed during the dynamic task. It can be argued that the pupil response may be strongly affected by the dynamic aspect of the task. The visual scanning necessary to manage the flow may be responsible of the high pupil dilation and corroborate similar results in the literature, for instance, in the context of air traffic control where elevated pupil dilation is found during traffic overload, i.e. when numerous aircraft are evolving at the radar screen. The dynamic task is a laboratory reproduction of situation assessment in complex dynamic systems (Woods 1988), with problem solving within a world in perpetual changes. The dynamic aspect of the task may have also plaid a great role on the pupil dilation. Thus, one may also pose that the dynamic aspect of the task, in particular when the time pressure was strong, has contributed to the strong pupil dilation.

Conversely, the cardiac parameters seemed to be more influenced by the verbal working memory and effortful reasoning involved by the deductive task. In accordance with our hypotheses and with other authors (Middleton et al. 2001; Morrison 2001), this finding suggests that different behavioral responses, in our precise case, different executive processes, may activate different brain sub-regions that produce different patterns of activity on distinct ANS outputs.

ANS Arousal and Task Time-Course Effect

Each task generated a specific pattern of cardiovascular activity in function of its intrinsic difficulty. The observed cardiovascular patterns were coherent with our expectations. Whereas the dynamic task achievement was accompanied by a diminution of the heart rate, no time course effect occurred specifically during the logical task. This pattern seems to show the reliability of the cardiac parameters to monitor the mental effort exerted during the early phase of the dynamic task and the sustained cognitive demand of the logical one. This parallel between task difficulty and evoked cardiac responses is in agreement with Critchley et al. (2005). For instance, he found increased blood pressure during effortful vs. effortless task associated with anterior cingulate cortex activity, considered to generate autonomic changes.

Another interesting result is that a global time course effect was observed during both tasks on the HR. Indeed, even if this effect mostly concerned the dynamic task, the global significant effect uncovers the existence of a task course effect, independent of the task itself. The task novelty plus the experimental situation may have created a psychological stress that had slightly biased ANS measurements. This short-term psychological stress could explain the slight decrease of the heart rate within the deductive task. It is reasonable to hypothesize that cardiac activity is linked to energy mobilization during executive performance but is also reflecting a simultaneous related psychological stress.

The same global time course effect was found for SBP and no significant interaction between task and task course was observed. This result suggests that the SBP could have been more sensitive to the related psychological stress or the anxiety generated by task novelty of both tasks than to their specific difficulty. In this way, the SBP could be a very sensitive measure of the emotional state of operators. On the above basis, more reliable measures of workload generated by a given task should imply a first exposure to the task to avoid a time-course effect due to a non-specific psychological stress. Moreover, given that the heart rate seemed to be more specifically affected by mental load (time-course effect only during the dynamic task) than by psychological stress, the cognitive monitoring of operators could be more reliable with this parameter. Future works will attempt to confirm this result.

Interestingly, the PD did not show any task course effect. The difficulty of the dynamic task was theoretically diminished after the first phase but the micro-world control necessitated a constant visual surveillance of the water levels in the tanks and visual attention remained strongly involved. Thus, the sustained increased PD during the whole task course might be linked to the high visual attention component. One might highlight the high dispersion of PD change during the two tasks, probably explained in part by the emotional susceptibility of the subjects.

Conclusion

The starting point of the study was an assumption that the psychophysiological variables to task demand may be differentially affected by our two neuropsychological tasks. We found that the evolution of the difficulty within the dynamic task was coherent with the observed increase of the heart rate during the first phase of the task and its decrease near the baseline at the end of the third phase where the cognitive effort and the action on valves are nearly inexistent. The SBP reveals less clear results with a time-course effect (i.e. a progressive decrease along the task) that appeared not specifically in the dynamic task but also in the deductive one, despite the fact that this latter generates a stable high mental load. This non task-specific time-course effect seems to illustrate an overall psychological stress created by the task performance, independently of its specific difficulty or its generated mental load variation. The psychological stress, linked to task novelty is certainly generated by the first exposure to the task but also by the fear to perform not properly. In a second time, the cognitive involvement required by the tasks is certainly a factor of extinction of the psychological stress: indeed cognition can also modulate emotion The complex relationship existing between dorsolateral prefrontal and ventromedial prefrontal cortices probably sustain a great part of these cross influences between emotion and cognition (Simpson et al. 2001a). Another important result was the observation of distinct effects of the tasks on ANS. The HR seemed to be more increased by the verbal and logical component of the deductive task whereas PD seemed to be more sensitive to the visual attention component of the dynamic task. Contrary to our expectations, the pupillary diameter showed no time-course effect during the dynamic task. The strong sensibility of the pupil response to the visual attention required all along the task may explain why the PD did not demonstrate the falling of mental effort consecutive to the strong dropping of the required valve management during the third period.

A major limitation of the study was that our hypotheses were intrinsically linked to the nature of the tasks: we assumed that the task difficulty was linked to greater mental demand during the early phase of the dynamic task. However, authors (Chi et al. 2003) found that the time pressure is a very sensitive and reliable factor for predicting information processing load. The difficulty of the deductive task was founded on its non-ecological aspect, in particular for non-expert subjects. The use of tools evaluating specifically workload (e.g. NASA TLX) and psychological stress or anxiety (e.g. Spielberger's trait/state Anxiety Inventory) felt by subjects after each task should have been measured to provide additional information and to help to disentangle psychological stress from task difficulty effects on ANS. Future works should included these two components.

The ANS measurements are a unique window on the internal state of humans and interest various frameworks. Neuropsychology, for instance for the assessment and the rehabilitation of patients (Mateer et al. 2005) that would be improved by the disentangling of the emotional impairments and the cognitive one's during the early stages of Alzheimer's disease. The affective computing offers new ways for people to communicate with computers, especially through the implementation of emotional sensors that require a high understanding of physiological outputs. The ANS measurements also concerns neuroergonomics (Parasuraman and Rizzo 2006) and human machine interaction (HMI) in the field of complex working situations where a permanent monitoring of the operators could avoid accident. As long as the operator is a key agent in charge of complex systems (e.g. air traffic controller) the definition of metrics able to predict his performance is a great challenge. For instance, the systolic blood pressure could be a very reliable indication of the experience of a high deleterious stress (e.g. potential source of air crashes, (Dehais et al. 2003) within an operator and give the opportunity to react quickly with countermeasures (e.g. a simple informative message with actions to perform) before reaching an irreversible situation. In this background, the choice of relevant physiological measurements that give clues on the operator's objective internal state in function of its working context is necessary.

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