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Impact of a visual decision support tool in project control: A comparative study using eye tracking

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ABSTRACT

This paper presents the results of a comparative study where two decision support tools in project control have been selected: the S-Curve and *Activity Gazer*. The objective of the research is to characterize the impact of the visual decision-support tool in project control on the project planner's decision. Using eye tracking, a within-subject experiment was conducted with 17 participants where they were asked to make a diagnostic on a project portfolio. Results show that, despite the fact that a representation using the S-Curve helps reduce the time of diagnostics, both tools seem to have the same effect on the quality of the diagnostic by the participant. Also, we find that a representation where *Activity Gazer* is present is less mentally demanding than a representation where the S-Curve is present. These results suggest that the S-Curve could be improved to reduce the mental charge needed to analyze it and that new visualization tools could help project planners in their daily work.

1. Introduction

The project planner has plenty of tools that can be used in his daily work. Montes-Guerra et al. [15] counted and critiqued 99 of them. Currently, it is the role of the planner to choose the correct tool for the task he is working on. Currently, there is no rational tool or process for comparing project control tools to help the planner choose the most appropriate tool for the task at hand. In addition, each project management standard (PMBoK, PRINCE2, AACE,…) lists a variety of project control tools or techniques without prescribing their use. In practice, the choice of tools or modes of representation of project data is imposed by project planning software selected by employers or imposed by clients. In order to address this issue, this research aims to determine whether the use of certain project control data representations influences the planner's decision-making process.

When you consider project control, there are only a limited number of visual tools to help the planner in the diagnosis of a project [18, 23]. The tools mostly used in North America [18] are the Gantt chart and the S-Curve, as described by the PMBOK [19]. These tools support the planner throughout the analysis of a project's performance with a focus on the project's costs and schedule.

These two tools have been used by project planners for several decades. For example, the S-Curve, part of the earned value methodology (EVM), was developed by the U.S. Department of Defense in 1967 [22]. In recent years, the research aims mainly on the improvement of forecasting the duration and final cost of a project calculated by the earned value methodology (EVM), as reflected in literature reviews [18, 23]. For examples, see the following works: [11], [17], and [24].

On the visual side of improvements proposed, Tory et al. has addressed the problem of comparing different schedule options for the scheduling or rescheduling task [21]. But before rescheduling a project, one has to determine if it is necessary or not to do so. Recent research has helped develop a new visualization tool for supporting the project planners in their diagnostic work of an active project: *Activity Gazer* [12]. The objective of Lee and Rojas was to create, in an intuitive visual environment, a visualization tool to help project managers "*quickly identify areas of concern during project monitoring and control and thereby enhance their efficiency and optimizes their performance*" [12].

The advent of this conceptual framework has led to the following question: what is the impact of the visual decision-support tool used in project control on the decision of the project planner? To measure the impact of a visual decision-support tool in project control, four

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objectives could be defined:

O1 - Determine the impact of a visual decision support tool in project control on the quality of the decision;
O2 - Investigate the impact of a visual decision support tool in project control on the decision time;
O3 - Study the impact of a visual decision support tool in project control on the perceived cognitive load of the project planner;
O4 - Qualify the cognitive load induced on the project planner by the visual decision support tools.

In the next section, this paper presents the necessary background about visual decision support tools in project control and their validation studies. Then, the methodology used is presented in Section 3 followed by the results in Section 4. Section 5 presents a discussion showing the implications of the results. The paper concludes in Section 6.

2. Background

In terms of visual tools in project control, the Gantt chart and the S-Curve should come immediately to mind. The Gantt charts were developed in 1919 as a group of charts to illustrate the performance of a manufacturer by representing the usage of machinery, employees and the production progress on a timeline [4]. Since then, this tool has become omnipresent for project control in many fields with very little or no adaptation at all [5].

In a Gantt chart, all the activities or tasks of the project are represented by horizontal bars. Their lengths are proportional to the duration of their activities. To represent the links between them, arrows are drawn. Those links are representing the antecedent of the activities. Four types are commonly used:

- end-beginning;
- end-end;
- beginning-beginning and
- beginning-end.

The first known use of the Gantt chart [5] as a project control tool was by Muther in 1944 [16].

One of the tools derived from the Gantt chart has been developed by Luz and Masoodian [14]. It consists of a temporal mosaic for a better use of space, especially on the screen, as the Gantt chart was originally developed for a paper medium [14]. They performed a study to validate their proposition where participants were presented a Gantt chart or a temporal mosaic and were asked to interpret some data from the charts as "*No more than 3 tasks should be scheduled for the same day. Is this a problem with the current plan?*." The answers were noted on accuracy, time to answer and perceived difficulty to answer.

Other visual tools were developed by Tory et al. [21]. These tools can be divided in three categories:

- graphical representation of constraint types;
- representation of network chains and
- comparison of alternatives for schedules.

They tested their propositions with a visual inspection technique [1] and a user-based study [8]. This user-based study was aimed to compare different schedules using traditional techniques or newly developed ones. The tasks performed by participants are comparable to those of [14]. The answers were noted on accuracy and time to answer.

Since 1967, the S-Curve has been used to assure the cost and schedule control of projects, as the Gantt chart and the techniques of the earned value methodology (EVM) [19]. On this graph of costs against time, three curves are drawn. The first one is the budgeted cost of work scheduled (BCWS) of the project. The form of the curve (S) gave the name of the graph. The two other curves, the actual cost of work performed (ACWP) and the budgeted cost of work performed (BCWP), are also drawn. The comparison of the three curves is an indicator of the project against its planned schedule or budget.

A majority of research of the S-Curve aims toward a better evaluation of the project's final cost and duration [18, 23]. For the visual representation, Demachkieh and Abdul-Malak [3] made a review of the literature where they show that most of the studies where graphical representation is discussed contains three attributes of the EVM: ACWP, BCWS and BCWP. A graphical outcome made its appearance in 2010 with a new index: the forecast budgeted cost for work scheduled (FBCWS) [13]. Liu and Su [13] present the index, but no application of it or case study where the FBCWS curve is used were found.

Activity Gazer is a new conceptual framework allying elements of the Gantt chart and indexes of the EVM [12]. In this model, a project can be represented like a solar system where activities orbit on different levels. Their size is correlated with the remaining budget of the activity and their colour (red, yellow or green) depends on the selected index and the thresholds fixed by the user. Traces appear on the orbits to illustrate the duration of the activity, as the bars of the Gantt chart. The colour of the trace changes from gray to black as the completion of the task occurs. Finally, a green line from the center of *Activity Gazer* to its border illustrate the state date of the project.

Their framework was presented to a panel of experts during the development stage to receive their comments and upgrade the framework. On a later user-based study, another group of experts were asked to perform basic tasks of project monitoring and identify discrepancies between the planned and effective progress. They were also asked to suggest corrective actions which would try to realign the project with its baseline. The data collected was aimed to assess the usefulness of *Activity Gazer* and receptiveness of the potential users towards the new tool.

All these visual tools could be considered as help for the project planner for decision support. Their respective authors have tested that their tool enables the user to perform the classical task it was built for, and if it performs better than the original tool. But the control stage of a project includes a diagnostic stage, where the planner has to examine the state of the project and decide whether a corrective action should be engaged, such as rescheduling, where tools developed by Tory et al. or Luz and Masoodian could intervene.

Other project control tools have not been tested yet to measure how they influence the planner's decision process. This study aims to fill part of this gap as it is designed to compare the influence of the S-Curve and *Activity Gazer* on the decision of a project planner performing a performance review.

3. Methodology

To answer the research question, a within-subject experimentation was conducted with 17 participants in a usability laboratory. Participants were asked to analyze a project portfolio and decide, for each project, whether or not a rescheduling is necessary to respect the project's deadline. The experimentation was approved by the ethic committee of the institution.

3.1. Experimental stimulus

The stimulus conception for this study refers to two main visualizations in project control. The first one is the S-Curve developed by the U.S. Department of Defense [22] and described by the PMBOK [19] as a tool of the earned value methodology (EVM). The second one is called *Activity Gazer* and was developed by Lee and Rojas [12]. The choice of these tools was guided from an indication of Lee and Rojas that their conceptual framework needed a comparison against the "traditional

Table 1
Elements in visualizations in experimental stimulus.

	Gantt	S-Curve	*Activity Gazer*
Duration of activity	X		X
Antecedence links	X		
Name of activity	X		X
Completion of activity	X		X
Critical path	X		X
Time scale of the project	X	X	X
Milestones	X		
SPI of the entire project		X	
SPI of each activity			X
Budget evolution of each activity			X

tools" of project control [12]. Pellerin and Perrier indicate that the "traditional tools" of project control are the Gantt chart and the S-Curve [18].

During a preceding phase of this study [9], some problems occurred using *Activity Gazer*. To fix these problems, some modifications were suggested to the framework [10]. The augmented visualization is employed in the current study.

Each visualization tool used in the experimental stimulus has some particularities. Table 1 shows the comparison of the different elements between the Gantt chart, the S-Curve and *Activity Gazer*. It is important to note that most of the elements present in a Gantt chart are also included in *Activity Gazer*. The main difference is that *Activity Gazer* presents the schedule performance index (SPI) (chosen for this experiment) for each activity and not only for the entire project, as the S-Curve.

Three different kinds of stimuli are used in this study. Those stimuli include respectively these elements:

Rep. A Gantt chart, *Activity Gazer*, SPI and information about resources;
Rep. B Gantt chart, S-Curve, SPI and information about resources;
Rep. C Gantt chart, *Activity Gazer*, S-Curve, SPI and information about resources (e.g. at Fig. 1).

Further references to the representations in this paper will use the letters here presented, e.g. *Rep. A* or *representation A* refers to the first stimulus described.

For the study, 25 fictive projects were developed. For each one, several project updates were made to obtain a project which is in its execution phase. Each project includes eight to thirteen activities. Projects were updated to be in time, in advance or late when compared with their baseline. The example given at Fig. 1 is a project that is late compared to its baseline.

Randomly, projects were separated in five groups of five projects. The first three groups presented each five projects of one type of representation. The last two groups included mixed representation. This separation enable the association of questionnaires of the first three groups to a specific type of representation. In total, the 25 projects used:

- 8 representations A;
- 8 representations B and
- 9 representations C.

Within each group, the order of presentations of the project was randomized. The first three groups were counterbalanced for the order of the representation used. For each of these projects, the participant was asked if a rescheduling is necessary to respect the planned end date of the project.

The stimulus was pretested with four participants to assure the duration of the task and the clarity of instructions. The number of stimuli presented was then fixed and some minor wording adjustments were made before the full study.

3.2. Participants

Two groups of participants took part in this study. The first is composed of nine professionals in project management. They were recruited by publicizing the study with the local branch of the Project Management Institute (PMI). Professional participants received a $40 Amazon gift card for their contribution to the study.

The second group is composed of students involved in a graduate program in project management in a major North American engineering school. They had to be a member of a project management research chair or to have followed or be enrolled in a specific graduate-level project management course. The eight participants of this group received a $40 gift card to be used at the school's bookstore.

3.3. Experimental protocol

The study is composed of five parts. First, the participant completes a sociodemographical survey. The second part is composed of two short videos on the project management tools used in the study. The first video presents the concepts of the Gantt chart, the S-curve and the SPI to ensure all participants use the same vocabulary during the study. The second video is a presentation of *Activity Gazer* as defined in [12] and ameliorated in [10].

In the third phase of the study, participants are presented with a test aimed at validating their comprehension of the videos shown in phases 1 and 2. As it is also used as a training task, wrong answers are explained to the participant.

The fourth part of the study is the main task and uses the stimulus described in Section 3.1. It is presented as a project portfolio composed of 25 projects. Putting aside the fact that the 25 projects were fictive, all other information given to the participants was on the representation presented with the format A, B or C. No other information was given to the participant. For each of them, the participant had to answer if, yes or no, the project needs a rescheduling to respect the planned end date of the project.To do so, the user simply pressed a keyboard touch (Y/N). The example in Fig. 1 was expected to be a "Yes, a rescheduling is necessary."

After reviewing each group of five projects of this portfolio, participants are asked to evaluate their perceived cognitive state. The NASA Raw-TLX [6] test was used to do so.

3.4. Apparatus and calibration

The eye movement was captured using SMI RED 250 eye-tracker (Red 250, SensoMotoric Instruments GmbH, Teltow, Germany). The sampling frequency was fixed to 60 Hz and a fixation duration threshold of 200 ms [7]. For each participant, a calibration was made at the beginning of the study. This calibration used a 5-point predefined calibration grid. A gaze-position deviation of 0.5° or less was accepted.

3.5. Measures

Measures obtained in this study involve different types. For the main task, the participant's behavioural response was recorded in regards to deciding if the project is on track or needs to be rescheduled. The behavioural response was then compared to the expected response when evaluating the project. The expected response for each stimulus was determined by two experts in project control. The quality of the behavioural response could then be stated as 1 if the response coincides with the expected one, and 0 if not. This response also includes the response time for which the decision was given.

This study included several questionnaires that were needed to meet the third objective. The NASA Raw-TLX [6] is commonly used to evaluate the perceived cognitive/work load. This test evaluates six components:

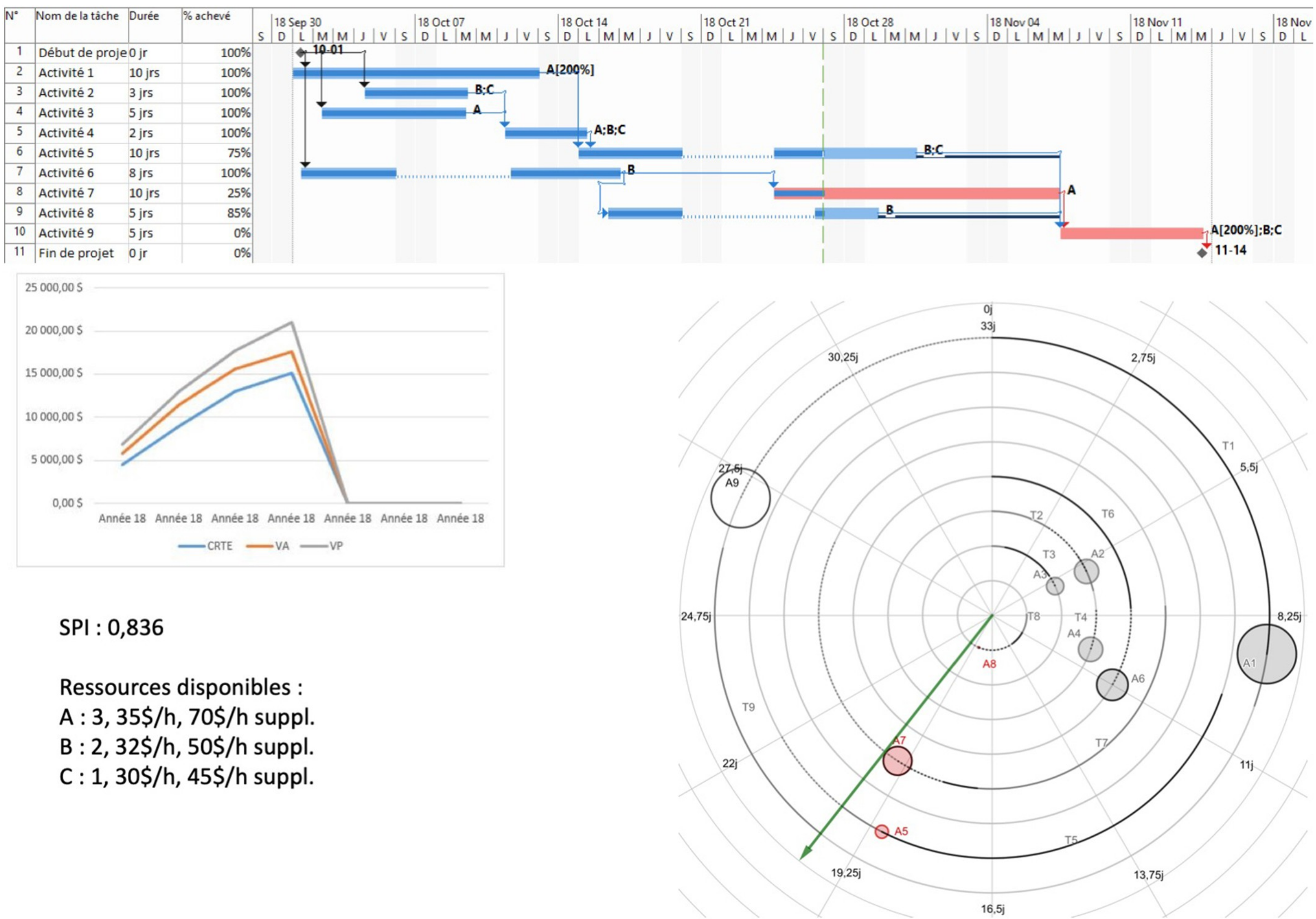

Fig. 1. Example of a project illustrated with the representation C. In french in the experiment. Please use the following translation for the terms on the figure: - Nom de la tâche: Name of the task - Durée: Duration - % achevé: % accomplished - Début du projet: Beginning of the project - Activité: Activity - Fin de projet: End of project - Ressources disponible: Resources available.
After the experimentation has begun, the authors observed the non-discriminant x-axis on the S-Curve graph. No participant made an observation about it during the experimentation.

1. mental exigence of the task;
2. physical exigence of the task;
3. temporal exigence of the task;
4. self-perceived performance of the participant in the task;
5. effort for the participant to do the task and
6. perceived frustration of the participant during the task.

These six components are noted on a 0–100 scale where 0 represents a low level of the component and 100 a high level.

To characterize the cognitive load induced and the visual attention, a different technique is necessary. Eye tracking was selected. During the evaluation of the project portfolio, eye tracking was used to collect the gaze of participants on the screen. The eye tracking was selected to measure the performance of the participant as it enables the collection of more precise data than only the reaction time, the accuracy or verbal reports. By its perceptual aspect, eye movements are a way to express the expertise to domain-related patterns or knowledge. The review of Reingold and Sheridan presents these elements applied to chess and radiology [20]. Eye-tracking is also an unconscious way to capture the decision taking process that is not possible to measure with other tools. It is an unobtrusive way to capture data as the participant naturally uses a computer [2]. This technique was used to meet the fourth objective described at the end of Section 1.

As the stimulus and task presented to the participants have some similitudes to the analysis of a chess board or a radiology test, the use of eye tracking and expertise theory is appropriated to collect more relevant information. Effectively, each stimulus is a static image. Each case contains a certain amount of information and could be associated to an error detection task.

The eye-tracking software allows the definition of several areas of interest (AOIs). For each case, depending on the type of representation, these AOIs are defined:

1. *Activity Gazer* (Rep. A and C);
2. Gantt chart (Rep. A, B and C);
3. S-Curve (Rep. B and C) and
4. SPI (Rep. A, B and C).

For each of those AOIs, the entry time in the area, the first fixation duration, the fixation count and the average fixation duration were collected. Also, for each fixation on a stimulus, the fixation duration, position and pupil diameter were collected. The position of the fixation is defined by the AOI where the fixation is made on the stimulus.

A pupillometry analysis allows the evaluation of the cognitive charge of the task [7]. Holmqvist et al. [7] have shown that the room's and stimulus' luminosity can interfere with the measurement of the participant's pupil diameter. The distance between the eye and the eye tracker could also impact the measured diameter. In the present study, the room's luminosity was controlled and all stimulus were of similar colour and luminosity. The participant was not in a fixed position. Head movements could then interfere with the measurement. Participants were asked during the study to return to the initial position if they moved from it. The analysis of the pupillometry data keep this possible interference in mind.

3.6. Analysis strategy

A correlation analysis combined with regression analysis is made. The first part of the analysis tried to confirm the same hypothesis as the first part of this study [9]: the influence of the visual representation used on the time of analysis of the participant; the performance of the participant and his confidence on his decision. The confidence level is the fourth parameter evaluated by the NASA Raw-TLX [6]. The analysis was conducted on the six parameters to determine if there is an influence on another parameter than only the confidence level.

A second part of the analysis used the eye tracking data. The fixation count, the average fixation time and the entry time in each AOI were analyzed to determine the significative coefficients.

Finally, the work load of the task was questioned to determine if certain zones or information in the task are more demanding for the participant. The evaluation of the workload was compared to the results of the parameters evaluated by the NASA Raw-TLX and the variation of the pupil diameter between the fixations made on each case and the baseline at the beginning of the study.

To assure the normality of the data, when needed, the natural logarithm of a variable was used. The square root or the inverse of the variable may be used if the normality of the variable is not reached with the natural logarithm.

For comparative necessity, as the representation B is the more spread in practice [18], this representation was used as the reference group when appropriate.

4. Results[1]

4.1. Quality of the decision

Each case presented to the participant has a decision associated. The quality of this decision is evaluated and is noted as 1 if it's the expected decision and 0 if not.

A first analysis of the data collected shows that a correlation exists between the order of presentation of the different cases and the quality achieved by the participants (0.219, p-value ≤ 0.001).

A logistic regression, including the order of presentation, is of the form:

$$Quality = \beta_1 \times Order + \beta_2 \times dPro + \beta_3 \times dRepA + \beta_4 \times dRepC + \beta_0 \tag{1}$$

For the quality, the influence of the type of representation or being a professional is not significant. The influence of the order of presentation is significant with a coefficient of 0.069, p-value ≤ 0.001.

4.2. Response time

The response time is evaluated as the moment, in milliseconds, when the participant makes his decision as whether the project needs a replanification.

A negative correlation appears between the natural logarithm of the response time and the representation B (-0.145, p-value ≤ 0.001), the order of presentation (-0.310, p-value ≤ 0.001) and the quality of the decision (-0.088, p-value ≤ 0.1).

[1] The analysis of this section was made using *Stata* software. All statistics are presented in the appendix. To ease the reading, only significant results will be presented in the body of the paper.

A linear regression analysis for the response time is of the following form:

$$\ln(ResponseTime) = \beta_1 \times Order + \beta_2 \times dPro + \beta_3 \times dRepA + \beta_4 \times dRepC + \beta_5 \times Quality + \beta_0 \tag{2}$$

The significant parameters of this equation are shown in Table 2. It should be noted that the coefficients of β_3 (0.254, p-value ≤ 0.01) and β_4 (0.279, p-value ≤ 0.01) are positive and seems to be of similar values.

As mentioned, there is a correlation between the natural logarithm of the response time and the quality achieved by the participant. But the quality is not a significant factor of the regression (2). Neither is the fact of being a professional in project management.

4.3. Perceived cognitive and work load

The perceived cognitive and work load is evaluated with the NASA Raw-TLX. The questionnaire evaluates six components, as mentioned in Section 3.5.

For the linear regression analysis of the components of the Raw-TLX, the general equation is of the following form:

$$TLX = \beta_1 \times Order + \beta_2 \times dPro + \beta_3 \times dRepA + \beta_4 \times dRepC + \beta_0 \tag{3}$$

Five of the six components of the NASA Raw-TLX are not correlated with a representation. The regression of Frustration as evaluated by the NASA Raw-TLX is the only regression that includes one of the representations. The significant parameters of this regression are presented in Table 3.

It is important to observe that the representation A induced a reduced perceived frustration to the participant than the representation B. This perceived frustration is then reduced by more than 5%, with a p-value ≤ 0.05.

4.4. Induced cognitive load

The induced cognitive load could be evaluated with several indicators measured during an eye-tracking study. Those factors are the count of fixations in a designed area of interest (AOI), the average fixation duration on an AOI, the entry time in an AOI, the dwell time and glances count in an AOI. Another factor is the variation of the diameter of the pupil of the participant during the fixations.

4.4.1. Fixation count

There is a correlation between being a professional and the natural logarithm of the fixation count made on the four AOIs considered. Those correlations are presented in Table 4.

For each of the AOI presented in Section 3.5, a regression analysis, based on the general form of Eq. (4), is done for the fixation count. For the four AOIs evaluated, no significant factor is part of the regression.

$$Y = \beta_1 \times Order + \beta_2 \times Quality + \beta_3 \times dPro + \beta_0 \tag{4}$$

When you consider the data for all fixations made on each stimulus, another regression analysis could be done. It's of the following form:

$$Z = \beta_1 \times Score + \beta_2 \times Order + \beta_3 \times dRepA + \beta_4 \times dRepC + \beta_5 \times dPro + \beta_6 \times AG + \beta_7 \times Gantt + \beta_8 \times S - Curve + \beta_9 \times SPI + \beta_0 \tag{5}$$

This regression analysis shows that the AOI has an impact on the

Table 2
Significant parameters of the linear regression for the natural logarithm of the response time (Eq. (2)).

Parameter	β_1 Order	β_3 Rep. A	β_4 Rep. C	β_0
Coefficient	−0.036****,**,****	0.254***	0.279***	10.614****

** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table 3
Significant parameters of the linear regression of the Frustration.

Parameter	β_1 Order	β_3 Rep. A	β_0
Coefficient	−0.769***,***	−5.383**	40.435****

** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table 4
Correlations for the fixation count.

	Activity Gazer	Gantt	S-Curve	SPI
dPro	−0.209****,***,****	−0.110**	−0.226****	−0.197****

** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

fixation count for the AOIs listed in Table 5. The impact of a good diagnostic, the expertise or the representation type is not significant for the fixation count on a stimulus.

4.4.2. Fixation duration

For each fixation in an AOI, the duration is evaluated. There is a correlation between being a professional and the natural logarithm of the average fixation duration in the considered AOIs. Those correlations are presented in Table 6.

It should be noted that all the significative correlations are negative and are linked to the fact of being a professional in project management. Also, it should be observed that the average fixation duration on the AOI of the Gantt chart is not correlated with being a professional.

The significant factors in the regressions of the general form of Eq. (4) explaining the average fixation duration in the AOI, except the order of presentation, are, for the following AOIs:

- *Activity Gazer*: Score, −0.206, p-value ≤0.1.
- S-Curve: dPro, −0.684, p-value ≤0.1.

When considering all fixations made on a stimulus, regression analysis of the general form of Eq. (5) on the natural logarithm of the average fixation duration shows that the AOI fixed has an impact for the following AOIs:

Table 6
Correlations for the average fixation duration.

	Activity Gazer	S-Curve	SPI
dPro	−0.101*,**,***	−0.212****	−0.162****

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

- Gantt chart, −0.127, p-value ≤0.01 and
- SPI, 0.146, p-value ≤0.01.

4.4.3. Entry time in AOI

The entry time is noted as the moment where the gaze of the participant enter a specified AOI. There is a correlation between being a professional and the natural logarithm of the entry time in the AOI of *Activity Gazer* (0.124, p-value ≤0.05). There is also a link between the score and the natural logarithm of the entry time in the AOI of the Gantt chart (−0.253, p-value ≤0.001).

For each AOI, there is no significant factor in the regressions explaining the entry time in the AOIs with the exception of the constant of the equation and the order of presentation of the cases for the AOI of the S-Curve.

4.4.4. Dwell time in AOI and glances count

The dwell time is defined as the time elapsed between an entry and an exit of a specific AOI. The glances count is the number of times the gaze of the participant has entered and exited a specific AOI [7].

For the dwell time in AOIs, there is a direct positive correlation (p-value ≤0.001) with the natural logarithm of the response time. A similar correlation (p-value ≤0.001) could be observed between the glances count and the natural logarithm of the response time. Simply, longer and more frequent a participant look at an AOI, it would take more time to take his decision.

For the regressions, except for the order of presentation or the constant β_0, there is no significant factors for regressions of the form of Eq. (6) explaining the quality achieved by the participant except the average dwell time in the S-Curve's AOI with a coefficient of 0.129, p-value ≤0.01.

$$\begin{aligned} Z &= \beta_1 \times Order + \\ &\beta_2 \times AG + \beta_3 \times Gantt + \\ &\beta_4 \times S - Curve + \beta_5 \times SPI + \beta_0 \end{aligned} \tag{6}$$

4.4.5. Pupillometry

The pupillometry data here considered consists of the difference of the pupil diameter during the fixation and the diameter during the baseline made at the beginning of the study for each fixation made by the participant.

A correlation analysis made on the average pupil diameter shows a link to the quality of the decision of the participant, the effect of being a professional, the representation C, and three of the AOIs. The significative correlation coefficients are presented in Table 7. It should be

Table 5
Significant parameters of the regression of the fixation count.

	β_2 Order	β_6 *Activity Gazer*	β_7 Gantt chart	β_9 SPI	β_0
Coefficient	−0.364****,**,***,****	−9.298****	−4.864****	−11.700****	19.542****

** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table 7
Correlations coefficients for the average pupil diameter.

	Score	dPro	Rep. B	Rep. C	*Activity Gazer*	Gantt	S-Curve
Avg Pupil Diameter	−0.089****,****	0.235****	0.078****	−0.046***	−0.089****	0.054***	−0.034*

* p-value: ≤0.1.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table 8
Significant parameters of the regression of the average pupil diameter.

	β_2 Order	β_3 Rep. A	β_6 *Activity Gazer*	β_7 Gantt chart	β_8 S-Curve	β_0
Coefficient	−0.006****	−0.038*	−0.078****	0.034***	−0.032**	−0.317****

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

observed that all the coefficients are negative except for the professionals and the AOI of the Gantt chart.

A regression analysis made on the difference of the pupil diameter between a fixation on a case and a baseline of the form of Eq. (5) has some significant parameters presented in Table 8. It should be noted that all the parameters are negative except for the AOI of the Gantt chart. In the regression analysis for the minimum, the maximum and the standard deviation of the pupil diameter, the same elements are significative at the exception of:

- the representation A, which is not significant for the maximum and the natural logarithm of the standard deviation;
- the S-Curve's AOI which is not significant for these analyses;
- the *Activity Gazer*'s AOI which is not significant for the minimum regression and
- the Gantt chart's AOI which is not significant for the maximum and the natural logarithm of the standard deviation.

5. Discussion

As it can be observed, the project representation type used has an impact on the response time of the participant. There is a negative correlation of the response time with representation B and positive regression coefficients with representations A and C. This is an expected result. The more usual tool, the S-Curve [18], gives a more efficient diagnosis than *Activity Gazer*, which was just explained to the participant.

The type of representation has an influence on the frustration perceived by the participant. Representation A, where *Activity Gazer* is present, is less frustrating for the participant than representation B, using only classical tools.

The variation of the pupil diameter observed on the *Activity Gazer*'s area of interest (AOI) could signify that the analysis of a case where *Activity Gazer* is not present could be more demanding mentally [7]. Effectively, the positive correlation of the pupil diameter and the representation B (p-value ≤0.001) and the negative regression parameter of the representation A for the average pupil diameter would tend to substantiate this interpretation.

The fixation count varies for the AOI observed. If we classify the parameters of the fixation count's regression by increasing order, we would obtain:

- SPI, −11.700, p-value ≤0.001;
- *Activity Gazer*, −9.298, p-value ≤0.001;
- Gantt chart, −4.846, p-value ≤0.001.

The fixation count on an AOI could be interpreted that a high number of fixations show that the information presented in this AOI is important or that the information contained in this AOI is difficult to interpret [7]. Given that the variation on pupil diameter shows a less demanding effort to analyze data presented in *Activity Gazer* and needs less fixations than the Gantt chart, the first interpretation should be excluded.

Finally, the performance of the participant is positively influenced by the average dwell duration in the AOI of the S-Curve. Three conclusions could be made, following [7]:

1. the information given by the S-Curve is important and it made the interest of the participant grow for this AOI;
2. the information given by the S-Curve is poor and brings uncertainty to the participant;
3. the information included in the S-Curve is difficult to extract or interpret.

Given the results, the first assumption could be excluded and, as the participant performs better, the third explanation should be retained.

The main application of these results for practitioners is the validation of *Activity Gazer* as a project control tool. Indeed, results show that there is an advantage for the planner to use *Activity Gazer* to represent the state of his projects as it is less mentally asking for the interpretation of the data.

Also, the data presented to the participant (see Fig. 1) is not available, on commercial project control software as *Microsoft Project*, on a unique screen. Results show that, to determine if a project needs a rescheduling to respect the planned end date, all information presented (Gantt chart, S-Curve, SPI) is necessary to make the decision. We could then assume that, to consult all the information, including *Activity Gazer* if it is one day implemented on a commercial software, a project planner should consult different reports and screens to make his decision. It should be useful to the planner to create a custom report where all the information is gathered together as a dashboard to help in the decision making process about the analyzed project.

6. Conclusion

The objective of this paper was to determine if the visual decision support tool chosen by the project planner has an impact on his decision. A user-base study was conceived to compare the influence of the S-Curve, one of the most usual tools in project control, and *Activity Gazer*, a new conceptual framework to illustrate the state of a project using the earned value methodology indexes. Professionals and students in project management were asked to perform a diagnostic of a project portfolio of 25 projects.

Results show that the diagnostic time is shorter for the S-Curve, at no significant difference on accuracy. Eye tracking analysis on significant areas of interest reveal that the interpretation of the state of the project is facilitated with *Activity Gazer*. The variation of the pupil diameter of participants and the reduced fixation count and duration are evidence that this representation is less demanding mentally to interpret the data than the S-Curve.

Three limits could be mentioned for this study. The first one is about the size of the projects presented to participants. They were composed of 8 to 13 activities. These are relatively small projects. A study where projects of a more comparable size to real-life projects should be conducted to confirm the results here obtained. This study could also confirm the capability of *Activity Gazer* to represent large-scale construction projects as intended by its authors [12]. A second limit is the absence of WBS in the projects used in the present study. A similar study with large-scale projects should use a WBS to decompose the projects presented to participants. A third limit is that only two visual decision support tools were used. This study was intended to be a first step to classify visual decision support tools in project control. Further studies should compare the other tools presented in Section 2 to obtain a classification of the most beneficial visual decision support tool in project control.

The current study compared *Activity Gazer* and S-Curve after a short tutorial on both tools. All participants were new to the conceptual framework of *Activity Gazer*. Because of this introduction of *Activity Gazer*, future studies should be conducted to confirm the efficacy of *Activity Gazer* in daily work. Then, the effect of novelty could be extracted from the study and maybe a performance impact could be observed.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Descriptive statistics

Table A.1
Descriptive statistics for the discrete variables.

	Ordre	dProfessionnel	drepresentation1	drepresentation2	drepresentation3	Score	AnswerTime (ms)	lAnswerTime
Mean	13.136	0.523	0.325	0.313	0.363	0.690	38 059.640	10.215
p50	13	1	0	0	0	1	30 150.800	10.314
sd	7.177	0.500	0.469	0.464	0.481	0.463	31 538.380	0.860
Min	1	0	0	0	0	0	1901.700	7.551
Max	25	1	1	1	1	1	211 657.300	12.263
Skewness	−0.020	−0.091	0.749	0.808	0.571	−0.820	1.775	−0.338
Kurtosis	1.812	1.008	1.561	1.653	1.326	1.673	7.414	2.812
N	419	419	419	419	419	419	419	419

	MentalExigence	**PhysicalExigence**	**lPhysicalExigence**	**TemporalExigence**	**Performance**	**Effort**	**Frustration**
Mean	56.461	13.344	1.767	36.780	67.594	53.544	29.024
p50	61	7	2.079	34	70	61	24
sd	18.745	17.591	1.465	23.797	16.611	21.718	25.511
Min	9	0	0	0	25	1	0
Max	91	71	4.277	100	100	100	91
Skewness	−0.672	1.606	0.033	0.354	−0.337	−0.612	0.722
Kurtosis	2.591	5.041	1.554	2.380	3.200	2.397	2.453
N	419	419	419	419	419	419	419

Table A.2
Descriptive statistics for the entry time in AOI (ms).

	AG	Gantt	S	SPI
Mean	3600.336	1560.625	3679.416	12 900.860
p50	1686.500	462.850	797.300	4208.150
sd	5092.135	3645.882	6863.315	20 049.400
Min	1.800	1.000	156.900	289.600
Max	31 962.200	37 147.100	71 326.100	157 739.200
Skewness	2.543	5.577	4.879	3.205
Kurtosis	10.552	41.499	40.090	17.982
N	279	408	261	194

	lAG	**lGantt**	**lS**	**lSPI**
Mean	7.207	6.241	7.111	8.491
p50	7.431	6.140	6.682	8.345
sd	1.608	1.550	1.467	1.457
Min	1.030	0.693	5.062	5.672

(*continued on next page*)

Table A.2 (*continued*)

	AG	Gantt	S	SPI
Max	10.372	10.523	11.175	11.969
Skewness	−0.546	−0.573	0.494	0.139
Kurtosis	3.555	5.023	2.007	2.091
N	279	408	261	194

Table A.3
Descriptive statistics for the fixation count.

	AG	lAG	Gantt	lGantt	S	lS	SPI	lSPI
Mean	46.528	3.467	38.251	3.129	10.937	1.959	0.885	0.456
p50	36	3.611	25	3.258	7	2.079	0	0
sd	38.429	1.045	40.503	1.164	13.915	1.048	1.368	0.555
Min	0	0	0	0	0	0	0	0
Max	210	5.352	244	5.501	97	4.585	10	2.398
Skewness	1.376	−1.208	2.118	−0.592	2.822	−0.034	2.531	0.912
Kurtosis	4.919	5.083	8.606	3.055	13.630	2.492	11.896	2.947
N	288	288	419	419	284	284	418	418

Table A.4
Descriptive statistics for the average fixation duration (ms).

	AG	lAG	Gantt	lGantt	S	lS	SPI	lSPI
Mean	361.148	5.704	317.059	5.586	287.963	5.198	181.647	2.699
p50	351.500	5.865	310.200	5.740	267.050	5.591	0	0
sd	120.545	1.060	117.497	0.973	164.530	1.599	252.689	2.929
Min	0	0	0	0	0	0	0	0
Max	757.900	6.632	799.700	6.685	916	6.821	1686	7.431
Skewness	−0.073	−4.862	0.330	−4.940	0.868	−2.713	1.766	0.195
Kurtosis	4.929	26.451	4.661	28.724	4.709	9.159	7.316	1.104
N	288	288	419	419	284	284	418	418

Table A.5
Descriptive statistics for the dwell time (ms).

	AG	sqrtAG	Gantt	sqrtGantt	S	lS	SPI	lSPI
Mean	18 368.780	122.496	13 991.080	102.007	4291.881	6.992	369.646	2.912
p50	13 806.800	117.507	9431.400	97.121	2019.600	7.611	0	0
sd	16 322.430	58.106	14 843.040	59.960	7121.434	2.467	751.924	3.188
Min	0	1	0	1	0	0	0	0
Max	103 563	321.814	90 309	300.516	65 921.500	11.096	6744.100	8.817
Skewness	1.807	0.387	1.779	0.531	4.340	−1.648	4.317	0.248
Kurtosis	7.498	3.349	6.704	2.867	29.523	5.573	27.884	1.201
N	288	288	419	419	284	284	418	418

Table A.6
Descriptive statistics for the glances count.

	AG	lAG	Gantt	lGantt	S	lS	SPI	lSPI
Mean	6.417	1.747	6.826	1.752	4.067	1.397	0.823	0.441
p50	5	1.792	4	1.609	3	1.386	0	0
sd	6.334	0.709	8.088	0.752	3.683	0.684	1.212	0.531
Min	0	0	0	0	0	0	0	0
Max	61	4.127	101	4.625	23	3.178	7	2.079
Skewness	3.397	0.056	5.061	0.270	2.026	−0.138	2.096	0.851
Kurtosis	23.374	3.273	48.581	3.324	8.572	2.906	8.270	2.735
N	288	288	419	419	284	284	418	418

Table A.7
Descriptive statistics for the average dwell time (ms).

	AG	lAG	Gantt	lGantt	S	lS	SPI	lSPI
Mean	3575.874	7.901	2308.550	7.371	905.791	6.399	425.864	5.867
p50	2685.286	7.896	1691.591	7.434	567.540	6.343	350.600	5.862
sd	3210.747	0.745	2166.888	0.904	920.947	0.905	333.264	0.599
Min	166.900	5.123	116.900	4.770	83.500	4.437	83.500	4.437
Max	27 933.130	10.238	18 696.200	9.836	5992.864	8.698	3372.100	8.124
Skewness	3.113	−0.031	2.583	−0.262	2.349	0.202	4.474	0.171
Kurtosis	17.790	3.684	13.982	2.842	10.199	2.237	35.320	3.666
N	279	279	408	408	261	261	194	194

Table A.8
Descriptive statistics for pupillometry data.

Stats	avgPupilD	minPupilD	maxPupilD	S.D.PupilD	lS.D.PupilD	Avg Fix. Dur.	l(avg Fix. Dur.)
Mean	−0.384	−0.546	−0.209	0.135	0.124	323.838	5.685
p50	−0.380	−0.510	−0.190	0.123	0.116	290.775	5.676
sd	0.231	0.308	0.238	0.085	0.072	163.136	0.431
Min	−1.220	−1.970	−1.140	0	0	83.400	4.436
Max	0.320	0.320	0.930	0.919	0.652	2404.600	7.786
Skewness	−0.225	−0.424	−0.185	1.648	1.143	2.707	0.283
Kurtosis	3.216	3.235	3.865	9.564	6.372	18.998	3.653
N	3302	3302	3302	2808	2808	3302	3302
	Min avg Fix.	**l(min avg Fix. Dur.)**	**Max avg Fix. Dur.**	**l(max avg Fix. Dur.)**	**S. D. avg fig dur**	**l(S.D. avg fix dur)**	**Fixation count**
Mean	162.550	4.962	718.207	6.293	207.024	5.009	11.837
p50	133.500	4.902	534.200	6.283	163.598	5.104	6
sd	120.119	0.466	607.809	0.752	173.387	0.911	17.977
Min	82.100	4.420	83.400	4.436	0	0	1
Max	2404.600	7.786	5642.200	8.638	1888.611	7.544	264
Skewness	5.694	1.271	2.372	0.112	2.440	−1.254	4.719
Kurtosis	64.348	5.342	11.980	2.589	13.074	7.378	39.659
N	3302	3302	3302	3302	2808	2808	3302
	dProfessionnal	**dScore**	**dRep1**	**dRep2**	**dRep3**		
Mean	0.507	0.707	0.338	0.255	0.407		
p50	1	1	0	0	0		
sd	0.500	0.455	0.473	0.436	0.491		
Min	0	0	0	0	0		
Max	1	1	1	1	1		
Skewness	−0.028	−0.909	0.684	1.126	0.378		
Kurtosis	1.001	1.827	1.467	2.268	1.143		
N	3302	3279	3302	3302	3302		

Appendix B. Correlation tables

Table B.1
Correlations for the discrete variables.

	Ordre	dPro	dRepA	dRepB	dRepC	Score	lATime	MentalEx	lPhysEx	TempoEx	Perfo	Effort
Ordre	1											
p-value												
dPro	0.018	1										
p-value	0.711											
dRepA	−0.056	0.009	1									
p-value	0.254	0.849										
dRepB	0.013	−0.015	−0.468	1								
p-value	0.790	0.757	0.000****									
dRepC	0.042	0.006	−0.523	−0.509	1							
p-value	0.394	0.911	0.000****	0.000****								
Score	0.219	−0.011	−0.009	−0.060	0.066	1						
p-value	0.000****	0.824	0.857	0.223	0.177							
lATime	−0.310	−0.078	0.073	−0.145	0.069	−0.088	1					
p-value	0.000****	0.109	0.135	0.003***	0.160	0.073*						
MentalEx	−0.162	0.112	0.008	−0.024	0.016	0.050	0.079	1				
p-value	0.001****	0.022**	0.870	0.620	0.750	0.309	0.109					
lPhysEx	0.013	0.439	0.000	−0.019	0.019	0.025	0.152	0.429	1			
p-value	0.798	0.000****	1.000	0.695	0.705	0.614	0.002***	0.000****				
TempEx	−0.161	0.490	−0.041	0.004	0.036	−0.015	0.035	0.639	0.476	1		
p-value	0.001****	0.000****	0.403	0.941	0.457	0.765	0.481	0.000****	0.000****			
Perfo	0.186	0.504	0.037	−0.009	−0.028	0.071	−0.454	0.029	−0.027	0.148	1	
p-value	0.000****	0.000****	0.451	0.860	0.573	0.147	0.000****	0.557	0.588	0.002***		
Effort	−0.098	0.189	−0.038	0.001	0.035	0.047	0.082	0.807	0.386	0.564	0.088	1
p-value	0.045**	0.000****	0.443	0.978	0.471	0.339	0.094*	0.000****	0.000****	0.000****	0.074*	
Frustr	−0.210	−0.320	−0.099	0.032	0.066	−0.124	0.222	0.001	−0.061	−0.094	−0.481	0.107
p-value	0.000****	0.000****	0.043**	0.518	0.179	0.011**	0.000****	0.986	0.217	0.056*	0.000****	0.029**

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.2
Correlations for the entry time AOI.

	Ordre	dProfessionnel	Score	l(AG)	l(Gantt)	l(S)	l(SPI)
Ordre	1						
p-value							
dProfessionnel	0.018	1					
p-value	0.711						
Score	0.219***,****	−0.011	1				
p-value	0.000	0.824					
l(AG)	0.009	0.124**	−0.026	1			
p-value	0.876	0.038	0.672				
l(Gantt)	−0.063	0.013	−0.083*	−0.253****	1		
p-value	0.208	0.791	0.093	0.000			
l(S)	−0.119*	0.018	0.066	0.000	−0.333****	1	
p-value	0.054	0.778	0.287	0.999	0.000		
l(SPI)	−0.059	0.063	0.010	0.017	−0.088	0.148*	1
p-value	0.415	0.384	0.889	0.849	0.226	0.091	

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.3
Correlations for the fixation count.

Fixation Count	Ordre	dProfessionnel	Score	lAG	lGantt	lS	lSPI
Ordre	1						
p-value							
dProfessionnel	0.018	1					
p-value	0.711						
Score	0.219*,****	−0.011	1				
p-value	0.000	0.824					
lAG	−0.230****	−0.209****	−0.070	1			
p-value	0.000	0.000	0.234				
lGantt	−0.211****	−0.110**	−0.046	0.532****	1		
p-value	0.000	0.025	0.347	0.000			
lS	−0.147**	−0.226****	−0.036	0.263****	0.284****	1	
p-value	0.013	0.000	0.548	0.001	0.000		
lSPI	−0.097**	−0.197****	−0.035	0.177***	0.127***	0.440****	1
p-value	0.047	0.000	0.473	0.003	0.010	0.000	

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.4
Correlations for the average fixation duration.

Avg Fix Dur	Ordre	dProfessionnel	Score	lAG	lGantt	lS	lSPI
Ordre	1						
p-value							
dProfessionnel	0.018	1					
p-value	0.711						
Score	0.219,**,***,****	−0.011	1				
p-value	0.000	0.824					
lAG	0.012	−0.101*	−0.077	1			
p-value	0.835	0.086	0.191				
lGantt	−0.078	0.003	−0.026	0.063	1		
p-value	0.112	0.945	0.601	0.288			
lS	0.026	−0.212****	−0.026	−0.020	−0.065	1	
p-value	0.662	0.000	0.667	0.804	0.278		
lSPI	−0.042	−0.162****	−0.054	0.042	0.023	0.297****	1
p-value	0.387	0.001	0.269	0.480	0.636	0.000	

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.5
Correlations for AOI glances and dwell time.

	sqrtDwellAG	sqrtDwellGantt	lDwellS	lDwellSPI	lGlancesAG	lGlancesGantt	lGlancesS	lGlancesSPI	Score	Order	lAnsTime
sqrtDwellAG	1										
p-value											
sqrtDwellGantt	0.490****	1									
p-value	0.000										
lDwellS	0.188**	0.187***	1								
p-value	0.020	0.002									
lDwellSPI	0.174***	0.076	0.385****	1							
p-value	0.003	0.119	0.000								
lGlancesAG	0.727****	0.672****	0.228***	0.194****	1						
p-value	0.000	0.000	0.005	0.001							
lGlancesGantt	0.498****	0.780****	0.315****	0.180****	0.762****	1					
p-value	0.000	0.000	0.000	0.000	0.000						
lGlancesS	0.277****	0.344****	0.849****	0.355****	0.416****	0.519****	1				
p-value	0.001	0.000	0.000	0.000	0.000	0.000					
lGlancesSPI	0.218****	0.112**	0.394****	0.938****	0.244****	0.230****	0.396****	1			
p-value	0.000	0.022	0.000	0.000	0.000	0.000	0.000				
Score	−0.056	−0.064	−0.027	−0.051	−0.052	−0.070	−0.048	−0.042	1		
p-value	0.347	0.189	0.649	0.298	0.379	0.153	0.426	0.393			
Order	−0.254****	−0.190****	−0.056	−0.058	−0.176***	−0.201****	−0.103*	−0.096*	0.219****	1	
p-value	0.000	0.000	0.350	0.241	0.003	0.000	0.084	0.050	0.000		
lAnsTime	0.827****	0.741****	0.335****	0.192****	0.795****	0.739****	0.463****	0.248****	−0.088*	−0.310****	1
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073	0.000	

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.6
Correlations for AOI average glance time.

	lAvgDwAG	lAvgDwGantt	lAvgDwS	lAvgDwSPI	Score	Order	lAnsTime
lAvgDwAG	1						
p-value							
lAvgDwGantt	0.089	1					
p-value	0.149						
lAvgDwS	0.134	−0.053	1				
p-value	0.132	0.401					
lAvgDwSPI	0.126	0.069	0.193**	1			
p-value	0.160	0.344	0.027				
Score	−0.032	0.006	0.024	0.003	1		
p-value	0.598	0.908	0.698	0.964			
Order	−0.136**,***	−0.092*	−0.131**	−0.002	0.219****	1	
p-value	0.023	0.063	0.034	0.980	0.000		
lAnsTime	0.226****	0.343****	0.211****	0.058	−0.088*	−0.310****	1
p-value	0.000	0.000	0.001	0.422	0.073	0.000	

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.7
Correlations for the pupillometry data - part 1.

	avg Pupil D	min Pupil D	max Pupil D	lS.D. Pupil D.	lavg Fix Dur	lmin Fix Dur	lmax Fix Dur	lS.D. Fix Dur	Fix Count	dPro	Score
Avg Pupil D	1										
p-value											
Min Pupil D	0.873****	1									
p-value	0.000										
Max Pupil D	0.759****	0.439****	1								
p-value	0.000	0.000									
lS.D. Pupil D.	−0.202****	−0.512****	0.315****	1							
p-value	0.000	0.000	0.000								
lavg Fix Dur	−0.057****	−0.073****	−0.005	−0.169****	1						
p-value	0.001	0.000	0.794	0.000							
lmin Fix Dur	0.141****	0.350****	−0.190****	−0.239****	0.337****	1					
p-value	0.000	0.000	0.000	0.000	0.000						
lmax Fix Dur	−0.149****	−0.307****	0.121****	−0.025	0.827****	−0.155****	1				
p-value	0.000	0.000	0.000	0.191	0.000	0.000					
lS.D. Fix Dur	−0.086****	−0.141****	0.025	−0.042**	0.765****	−0.164****	0.871****	1			
p-value	0.000	0.000	0.190	0.027	0.000	0.000	0.000				
Fix Count	−0.179****	−0.392****	0.153****	0.108****	0.181****	−0.407****	0.498****	0.271****	1		
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
dPro	0.235****	0.185****	0.173****	−0.040**	0.027	0.012	0.009	0.050***	−0.054***	1	
p-value	0.000	0.000	0.000	0.036	0.122	0.502	0.590	0.008	0.002		
Score	−0.089****	−0.062****	−0.063****	0.044**	−0.001	0.040**	−0.025	−0.025	−0.048***	−0.022	1
p-value	0.000	0.000	0.000	0.020	0.952	0.024	0.161	0.197	0.006	0.215	
dRep1	−0.024	−0.027	−0.019	−0.009	0.029*	−0.004	0.035**	0.032*	0.031*	0.018	−0.001
p-value	0.170	0.116	0.273	0.644	0.094	0.842	0.042	0.093	0.073	0.313	0.938
dRep2	0.078****	0.055***	0.073****	−0.004	−0.004	0.006	−0.005	−0.015	−0.018	0.007	−0.059****
p-value	0.000	0.002	0.000	0.852	0.827	0.720	0.792	0.431	0.298	0.711	0.001
dRep3	−0.046***	−0.023	−0.046***	0.012	−0.025	−0.002	−0.030*	−0.017	−0.014	−0.023	0.053***
p-value	0.008	0.191	0.008	0.540	0.156	0.900	0.085	0.360	0.421	0.193	0.002
AG	−0.089****	−0.019	−0.159****	−0.049***	−0.010	0.090****	−0.079****	−0.033*	−0.099****	−0.001	0.011
p-value	0.000	0.265	0.000	0.010	0.578	0.000	0.000	0.077	0.000	0.972	0.530
Gantt	0.054***	0.043**	0.027	0.001	−0.084****	−0.007	−0.089****	−0.078****	−0.059****	0.006	0.009
p-value	0.002	0.014	0.119	0.975	0.000	0.699	0.000	0.000	0.001	0.725	0.599
S	−0.034*	−0.033*	0.003	0.042**	−0.025	−0.039**	−0.006	−0.021	−0.012	−0.005	0.003
p-value	0.050	0.055	0.846	0.027	0.151	0.026	0.713	0.273	0.484	0.773	0.885
SPI	0.018	0.111****	−0.119****	−0.093****	0.086****	0.319****	−0.091****	−0.002	−0.130****	−0.029*	−0.005
p-value	0.312	0.000	0.000	0.000	0.000	0.000	0.000	0.903	0.000	0.095	0.798

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table B.8
Correlations for the pupillometry data - part 2.

	dRep1	dRep2	dRep3	AG	Gantt	S	SPI
dRep1	1						
p-value							
dRep2	−0.418*,****	1					
p-value	0.000						
dRep3	−0.592****	−0.484****	1				
p-value	0.000	0.000					
AG	0.073****	−0.139****	0.053***	1			
p-value	0.000	0.000	0.002				
Gantt	−0.014	0.069****	−0.047***	−0.075****	1		
p-value	0.407	0.000	0.006	0.000			
S	−0.195****	0.151****	0.053***	−0.065****	−0.087****	1	
p-value	0.000	0.000	0.002	0.000	0.000		
SPI	−0.010	0.034**	−0.021	−0.056***	−0.074****	−0.065****	1
p-value	0.561	0.050	0.239	0.001	0.000	0.000	

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Appendix C. Regression tables

Table C.1
Regressions for the discrete variables.

Variable		Score	lAnswerTime	MentalExigence	lPhysicalExigence	TemporalExigence	Performance	Effort	Frustration
Ordre	**Coef.**	0.069*,****	−0.036****	−0.423**	0.003	−0.543**	0.436**	−0.305	−0.769***
	(S.E.)	0.013	0.008	0.197	0.010	0.216	0.173	0.227	0.235
	p-value	0.000	0.000	0.048	0.807	0.023	0.022	0.197	0.005
dProfessionnel		−0.072	−0.130						
		0.236	0.288						
		0.759	0.658						
dRepA		0.218	0.254***	0.587	0.044	−1.922	1.408	−1.438	−5.383**
		0.237	0.081	2.793	0.117	2.729	2.088	3.244	1.853
		0.357	0.006	0.836	0.715	0.491	0.510	0.663	0.010
dRepC		0.391	0.279***	1.172	0.077	1.159	−0.507	1.050	1.221
		0.337	0.084	2.261	0.134	2.750	1.544	3.022	1.989
		0.247	0.004	0.611	0.574	0.679	0.747	0.733	0.548
Score			−0.059						
			0.081						
			0.473						
_cons		−0.228	10.614****	61.407****	1.692****	44.118****	61.593****	57.634****	40.435****
		0.304	0.224	5.646	0.392	5.668	5.065	5.535	7.867
		0.454	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Statistics									
N		419.000	419.000	419.000	419.000	419.000	419.000	419.000	419.000
ll		−248.173	−503.457	−1816.400	−753.888	−1915.980	−1763.600	−1881.270	−1938.970
ll_0		−259.491	−530.917	−1822.090	−754.019	−1922.080	−1771.460	−1883.770	−1951.210
chi2		44.503							
F			9.483	2.125	0.216	5.960	3.129	1.353	5.297
r2			0.123	0.027	0.001	0.029	0.037	0.012	0.057
r2_p		0.044							
r2_a			0.112	0.020	−0.007	0.022	0.030	0.005	0.050
p		0.000	0.000	0.137	0.884	0.006	0.055	0.293	0.010

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table C.2
Regressions for the Entry Time in AOI.

Variable		lAG	lGantt	lS	lSPI
Ordre	**Coef.**	0.003	−0.010	−0.028*,**,***	−0.014
	(S.E.)	0.014	0.019	0.016	0.021
	p-value	0.860	0.593	0.097	0.526
dProfessionnel		0.394	0.043	0.078	0.211
		0.344	0.296	0.338	0.397
		0.268	0.886	0.820	0.604
Score		−0.077	−0.243	0.277	0.082
		0.264	0.142	0.166	0.313
		0.775	0.106	0.115	0.797
_cons		7.024****	6.519****	7.258****	8.517****
		0.280	0.205	0.237	0.279
		0.000	0.000	0.000	0.000
Statistics					
N		279	408	261	194
ll		−525.617	−755.314	−466.932	−346.890
ll_0		−527.856	−757.193	−469.894	−347.760
chi2					
F		0.748	1.222	1.789	0.222
r2		0.016	0.009	0.022	0.009
r2_p					
r2_a		0.005	0.002	0.011	−0.007
p		0.539	0.334	0.190	0.880

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table C.3
Regressions for the fixation count.

Variable		lAG	lGantt	lS	lSPI
Ordre	**Coef.**	−0.032**	−0.034***	−0.019*	−0.007
	(S.E.)	0.011	0.009	0.010	0.005
	p-value	0.011	0.002	0.084	0.186
Score		−0.075	−0.004	−0.022	−0.019
		0.145	0.110	0.176	0.061
		0.612	0.971	0.902	0.755
dProfessionnel		−0.433	−0.246	−0.457	−0.217
		0.293	0.433	0.286	0.164
		0.158	0.577	0.129	0.204
_cons		4.161****	3.705****	2.471****	0.675****
		0.268	0.332	0.228	0.138
		0.000	0.000	0.000	0.000
Statistics					
N		288	419	284	418
ll		−406.318	−645.703	−405.573	−336.144
ll_0		−420.885	−57.708	−415.755	−346.430
chi2					
F		5.529	5.745	3.903	2.024
r2		0.096	0.056	0.069	0.048
r2_p					
r2_a		0.087	0.049	0.059	0.041
p		0.008	0.007	0.029	0.151

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table C.4
Regressions for the average fixation duration.

Variable		lAG	lGantt	lS	lSPI
Order	**Coef.**	0.005	−0.010	0.010	−0.012
	(S.E.)	0.008	0.009	0.014	0.021
	p-value	0.583	0.294	0.505	0.575
Score		−0.206*,**,***	−0.019	−0.105	−0.310
		0.099	0.096	0.183	0.185
		0.055	0.847	0.574	0.113
dProfessionnal		−0.223	0.009	−0.684*	−0.950
		0.268	0.208	0.332	0.891
		0.418	0.966	0.056	0.302
_cons		5.906****	5.730****	5.497****	3.564****
		0.105	0.099	0.231	0.681
		0.000	0.000	0.000	0.000
Statistics					
N		288	419	284	418
ll		−422.215	−581.228	−528.978	−1035.450
ll_0		−424.813	−582.520	−535.854	−1041.860
chi2					
F		2.016	0.690	1.525	3.582
r2		0.018	0.006	0.047	0.030
r2_p					
r2_a		0.008	−0.001	0.037	0.023
p		0.152	0.571	0.2463892	0.037

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table C.5
Regressions about the score and lAnswerTime with AOI consultation by the participant.

Variable		Score	lAnswerTime	Score	lAnswerTime	Score	lAnswerTime
Ordre	**Coef.**	0.007*	−0.009***	0.008**	−0.014**	0.001	−0.041****
	(S.E.)	0.004	0.003	0.004	0.006	0.006	0.010
	p-value	0.074	0.007	0.046	0.024	0.889	0.001
sqrtDwellAG		0.000	0.008****				
		0.001	0.001				
		0.914	0.000				
sqrtDwellGantt		0.000	0.006****				
		0.001	0.001				
		0.652	0.000				
lDwellS		0.005	0.047****				
		0.018	0.011				
		0.792	0.001				
lDwellSPI		−0.003	0.006				
		0.016	0.009				
		0.878	0.481				
lGlancesAG				−0.014	0.575****		
				0.084	0.102		
				0.865	0.000		
lGlancesGantt				−0.007	0.325**		
				0.063	0.122		
				0.908	0.017		
lGlancesS				0.043	0.136		
				0.087	0.081		
				0.630	0.115		
lGlancesSPI				−0.018	0.016		
				0.096	0.070		
				0.851	0.818		
lAvgDwTimeAG						−0.032	0.212
						0.079	0.154
						0.688	0.191
lAvgDwTimeGantt						0.042	0.321**
						0.065	0.114
						0.529	0.015
lAvgDwTimeS						0.129***	0.152*
						0.036	0.074
						0.004	0.060
lAvgDwTimeSPI						0.025	−0.126
						0.089	0.144
						0.786	0.396

(*continued on next page*)

Table C.5 (*continued*)

Variable	Score	lAnswerTime	Score	lAnswerTime	Score	lAnswerTime
_cons	0.628****	8.493****	0.620****	8.770****	−0.316	6.896***
	0.154	0.179	0.128	0.196	0.435	1.838
	0.001	0.000	0.000	0.000	0.481	0.002
Statistics						
N	152	152	152	152	64	64
ll	−90.666	−23.223	−90.619	−99.625	−37.209	−57.095
ll_0	−92.205	−192.157	−92.205	−192.157	−39.652	−74.308
chi2						
F	1.210	64.360	1.385	53.647	5.522	22.580
r2	0.020	0.892	0.021	0.704	0.074	0.416
r2_p						
r2_a	−0.014	0.888	−0.013	0.694	−0.006	0.366
p	0.349	0.000	0.282	0.000	0.006	0.000

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

Table C.6
Regression for the pupillometry data.

Variable		Avg Pupil D	Min Pupil D	Max Pupil D	lS.D. Pupil D	lAvg Fix Dur	lMin Fix Dur	lMax Fix Dur	lS.D. Fix Dur	Fix Count
Score	**Coef.**	−0.024	−0.029	−0.003	0.008	0.008	0.025	−0.007	−0.028	−0.889
	(S.E.)	0.024	0.034	0.017	0.005	0.021	0.033	0.037	0.041	1.317
	p-value	0.324	0.406	0.858	0.139	0.720	0.460	0.854	0.513	0.509
Order		−0.006****	−0.003**	−0.009****	−0.001**	−0.002	0.006****	−0.010**	−0.004	−0.364****
		0.001	0.001	0.001	0.000	0.002	0.001	0.004	0.004	0.066
		0.000	0.016	0.000	0.041	0.368	0.000	0.013	0.266	0.000
dRepA		−0.038*	−0.046*	−0.030	0.005	−0.002	−0.018	0.014	0.022	1.046
		0.022	0.025	0.022	0.004	0.028	0.026	0.042	0.042	1.322
		0.100	0.085	0.183	0.169	0.954	0.510	0.752	0.601	0.440
dRepC		−0.035	−0.033	−0.033	0.005	−0.026	−0.013	−0.043	−0.024	0.061
		0.029	0.032	0.027	0.004	0.021	0.017	0.037	0.047	1.243
		0.247	0.319	0.251	0.243	0.244	0.458	0.262	0.609	0.962
dPro		0.110	0.119	0.083	−0.008	0.035	0.020	0.027	0.107	−1.856
		0.083	0.111	0.054	0.014	0.058	0.068	0.099	0.095	2.932
		0.203	0.300	0.144	0.564	0.558	0.768	0.791	0.275	0.536
AG		−0.078****	−0.005	−0.166****	−0.017***	−0.027	0.226****	−0.318****	−0.188*	−9.298****
		0.019	0.021	0.023	0.005	0.039	0.042	0.046	0.102	1.344
		0.001	0.832	0.000	0.006	0.495	0.000	0.000	0.083	0.000
Gantt		0.034***	0.048***	0.003	−0.001	−0.127***	0.032	−0.280****	−0.257**	−4.846****
		0.011	0.015	0.017	0.004	0.043	0.030	0.085	0.111	1.113
		0.006	0.005	0.880	0.821	0.009	0.291	0.005	0.034	0.000
S		−0.032**	−0.028	−0.012	0.010	−0.044	−0.022	−0.072	−0.100	−1.846
		0.015	0.028	0.017	0.009	0.070	0.027	0.123	0.136	1.429
		0.045	0.326	0.502	0.275	0.532	0.440	0.565	0.471	0.215
SPI		0.018	0.158***	−0.133***	−0.041***	0.146***	0.677****	−0.361****	−0.053	−11.700****
		0.034	0.041	0.035	0.011	0.048	0.056	0.078	0.136	1.717
		0.601	0.001	0.002	0.001	0.008	0.000	0.000	0.705	0.000
_cons		−0.317****	−0.527****	−0.088*	0.128****	5.711****	4.816****	6.504****	5.081****	19.542****
		0.073	0.096	0.045	0.010	0.063	0.063	0.094	0.103	3.108
		0.000	0.000	0.069	0.000	0.000	0.000	0.000	0.000	0.000
Statistics										
N		3262	3262	3262	2774	3262	3262	3262	2774	3262
ll		333.326	−73.979	319.018	3477.350	−1855.240	−1917.920	−3633.480	−3651.550	−13956.600
ll_0		146.655	−778.898	51.782	3441.940	−1884.530	−2136.010	−3698.480	−3671.100	−14062.500
chi2										
F		26.801	21.599	28.465	11.218	7.553	49.155	43.891	8.200	14.282
r2		0.108	0.062	0.151	0.025	0.018	0.125	0.039	0.014	0.063
r2_p										
r2_a		0.106	0.060	0.149	0.022	0.015	0.123	0.036	0.011	0.060
p		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

* p-value: ≤0.1.
** p-value: ≤0.05.
*** p-value: ≤0.01.
**** p-value: ≤0.001.

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