Don’t miss your train! Just follow the computer screen animation: Comprehension processes of animated public information graphics

Abstract

Computer graphic animated information displays have the potential to communicate public information in situations where normal announcement types are ineffective. This study used eye tracking techniques to analyze comprehension mechanism of event-related information on railway traffic disruptions presented via different graphic formats presented on computer screen. 86 participants were asked to understand series of traffic disruption messages delivered via four purely visual formats: Static simultaneous, Static sequential, Animated simultaneous and Animated sequential. Across these four conditions, and contrary to the most common materials used in the studies on animation comprehension, the sequentiality and the animated properties of the entities of the presentation were not confounded. Results revealed the Animated sequential displays were the most effective presentation type. Eye tracking data showed why an animation facilitates comprehension of public information graphics: it enhances processing strategies which provide the best condition for segmenting and composing the causal chain of the events provided in the message.

Key words: Animation formats, Public information, Disruption messages, Comprehension, Eye movements.

1. Introduction

The growth of technology has seen computers become widely used to deliver real time public information messages on platforms ranging from large displays screen to individual mobile devices. Such displays are increasingly common in railway stations, airports, bus terminals and city centers. Information that is useful or even critical to the public can change frequently and suddenly. Today’s global society is highly dependent on various forms of travel and any disruptions to those services can have major consequences. Travelers therefore need access to efficient, effective information sources so that they can respond rapidly and appropriately to such disruptions. Recent major travel disruptions in Europe exposed severe shortcomings in existing ways of presenting information that exacerbated an already chaotic situation.

Unfortunately, the design of important public information to be displayed on electronic screens is rarely based on empirical studies. Rather, the basis for their design tends to be intuition or traditional text-based approaches such as those that have evolved for railway station loudspeaker announcements and information boards. An overarching motivation for the research reported in this paper is to provide information that could guide the design of more effective and efficient railway disruption messages for the National French Railway Organization (SNCF).

The present paper explores the potential of dynamic *graphics*-based display screens, composed of series of dynamic pictographs, as alternatives to current spoken or written approaches for presenting public information about train traffic disruptions. Such information should be readily available and comprehensible to a broad cross-section of travelers[1] including the elderly, those with hearing impediments, and foreign travelers who are not familiar with the local language. Graphic messages could also assist travelers in general who cannot hear the usual loudspeaker announcements properly because of ambient station noise or their distance from loudspeakers. The experimental study presented here investigated the effect of different types of graphic design format on the comprehension of traveler action messages.

1.1. Visual alternatives to traditional spoken announcements: how to convey train announcements "non-verbally".

The conventional spoken railway announcements typically follow a standard format. In French stations, the texts that are spoken for these announcements are structured in terms of a succession of related events such as: *"Your attention please. Contrary to the information that has been displayed, the Regional Train (TER) number 3458 for Paris, will not start from platform B but*

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[1] This research is closely aligned with the European program, *"Access 2 all" (www.access-to-all.eu)* which concerns "mobility schemes ensuring public transport accessibility for all users", 2010.

will start instead from platform D. Please take the stairs to access platform D". The formulaic nature of these announcement texts gives them much in common with script schemas (Armbruster, 1996; Mandler, 1984). In some railway systems, disruptions can be a part of the everyday context of train travel. Travelers often have to comprehend and respond appropriately to disruption-related information under considerable time pressure. How to convey train announcements non-verbally? Graphic messages, cycling on computer screens distributed around the station could be an effective alternative to traditional spoken or written announcements (Figure 1).

Insert Figure 1 about here

In railway stations, announcement texts for the most common disruption-related loudspeaker messages are structured as an ordered sequence. Examples of messages include switching of a railway platform, delay of a train, cancellation of a train, reduction of services due to a strike, or consequences of extreme weather (snow, ice etc.); and a message related to general safety, passing of a nonstop high speed train on the railway near the passengers. Regular train travelers typically possess knowledge structures in long term memory that represent such event-related information as scripts (event schemas) that include various slots. The content of most messages that travelers hear in train stations may also be thought of in terms of categorical slots that can be populated with specific types of information. A typical structure is: (i) a warning *("your attention please")* (ii) the cause of the disruption ("*because of the snow*") (iii) the effect of that disruption *("the regional train number1556 for Paris, will be delayed by 15 minutes")* and (iv) the action that the traveler should take as a result (*"for further information please check the central panel situated in the main hall"*). Depending of the type of disruption, this series of four event slots may or may not all be filled. For example, in the following message, the causal event is not given: "*Your attention please, contrary to the information displayed previously, the Regional Train (TER) number 3458 for Paris, will not start from platform B but will start from platform D, please take the underground pathway*". Each event slot could be defined as an "episode" which applies on different (but limited in numbers) objects (such as a train, a platform, a stair, city name panels etc.). Regular train travelers in France are often exposed to such messages and so typically develop knowledge structures in long term memory representing relevant event-related information as scripts for various scenarios. In order to convey train announcements, which are (well) known events episodes with their usual objects, series of dynamic visual icons or dynamic pictographs could be developed.

In everyday life, single static pictographs are widely (and efficiently) used in different domains such as traffic and road signs, public areas, human-machine interfaces, industrial areas (for safety purposes), healthcare centers etc. Previous studies in this field of "information design" and or "iconic communication" have been focused mostly on taxonomies of pictographs and on the testing of their usability (Bodenreider, 2004; Familant & Detweiler, 1993; Isherwood, McDougall, & Curry, 2007; Nakamura & Zeng-Teitler, 2012; Rogers, 1989; Yazdani & Barker, 2000; Zwaga, Boersema & Hoonhout, 1999). Conveying information with pictographs "relies on pre-established code and convention" (Nakamura & Zeng-Teitler, 2012, p. 535) and implies the meaningful relation between the referent and the pictorial representation is quite transparent, direct or known. In the example of the train disruptions, the meanings of the referents in the context of the railway station are common. Such familiarity could help in understanding the graphic representation of the events and objects of the disruption.

In previous studies on visual pictographic representations, three levels of external pictorial representations of the referent have been identified (see the recent taxonomy by Nakamura & Zeng-Teitler, 2012, and the reviews in the book by Zwaga & al., 1999). (i) Direct representations use the visual similarity between a pictograph and its referent (for example, the picture of TGV train to refer to a TGV); (ii) arbitrary representations use social convention (for example the letter P to refer to a parking area, the letter I to refer to an information point); (iii) indirect representations use semantic relation, and semantic association, between a pictograph and its referent (for example, the picture of a fork and a knife to represent the concept of restaurant, or the picture of a clock to represent time and delays, see figure 2, first message). Different subcategories of semantic association were recently proposed by Nakamura & Zeng-Treitler (2012) in the domain of healthcare: comparison or contrast, exemplification, semantic narrowing, physical decomposition, temporal decomposition, body language, metaphor and contiguity.

The visual alternatives to spoken disruption messages built in this study were closely in line with recent taxonomies and associated recommendations. However, in previous studies, and in everyday situations as well (i) one graphic representation is usually presented alone in a single picture format (but see exceptions with series of static simultaneous pictographs in Dewar and Arthur, 1999, or in Nakamura & Zeng-Treitler, 2012); (ii) further, pictographs refer mostly to entities and objects (more than 86% of the pictographs used in the study by Nakamura & Zeng-Teitler, 2012, cf. page 542) and rarely to dynamic events and actions; (iii) until now, the presentation of the graphic is always (at least mostly) static. Finally, very few studies on pictographic communication are focused on comprehension mechanism.

Because train messages are composed of series of predetermined categorical slots, each message must be presented with a series of several pictures, instead of a single pictograph. In the present study, we used a composition of (dynamic) pictographs to depict complete messages which convey a complex meaning about train disruptions. Further, in the train messages, events described via the loudspeaker announcements, have key dynamic dimensions. They do not deliver information about static statement like do a majority of the pictographs printed on physical panels (Nakamura & Treiltler, 2012). Finally, train messages are structured according to a fixed temporal sequence. How to use visual graphics to present a sequence of dynamic concepts? It could be relevant to follow "the syntax structure" of the loudspeaker well known messages and to build sequences of graphics in which the relation between the referent and the representation would be as close as possible.

The goal of the two research questions investigated in the present article was to study (i) whether it helps comprehension of visual messages to present the graphics of dynamic events and concepts dynamically rather than statically, and (ii) whether the graphics should be presented sequentially or simultaneously.

1.2. Could animations enhance public information comprehension?

Current technology allows graphics and pictographs to be animated rather than merely static. In contrast with static graphics, animations are able to deliver explicit, precise and continuous information about the fine detail of events and process dynamics (Lowe & Boucheix, 2010; Lowe & Schnotz, 2008; Tversky, Bauer-Morrison & Bétrancourt, 2002). Most previous research on the comprehension of animated graphics has concerned formal instruction in scientific and technical domains (e.g., Bernay & Bétrancourt, 2009; De Köning & Tabbers, 2011; Höffler & Leutner, 2007; Ploetzner & Lowe, 2012; Scheiter & Eitel, 2010; Lowe & Schnotz, 2008). However, by focusing on the provision of public information in an informal, non-educational context, the present investigation extends the scope of animation research into a rather different but most important area that hitherto has remained essentially unexplored in this way. Its goal was to test the effect of different graphic presentation formats on comprehension of train disruption messages.

In previous literature, one main reason why animated graphics are supposed to be better than their static counterparts is because they present information about the micro steps of dynamic processes (Bétrancourt, 2005; Lowe & Schnotz, 2008; Tversky, Bauer-Morisson & Bétrancourt, 2002). The presence of this fine detail should assist viewers to build higher quality a mental model of the referent's dynamics (Hegarty, 2004; Hegarty, Canham & Fabrikant, 2010; Lowe & Boucheix, 2008, 2011, 2012). Two recent meta-analyses (Berney & Bétrancourt, 2009; Höffler & Leutner, 2007) reported an overall superiority of animations over static graphics with medium effect sizes ($d = .31$ and $d = .37$ respectively). However, other studies (for example, Boucheix & Schneider 2009; Hegarty, 2004; Kriz & Hegarty, 2007; Mayer, Hegarty, Mayer & Campbell, 2005) have shown that under some circumstances a series of static pictures (key frames depicting the main steps of the referent process, Spanjers, Van Gog & Van Merrienboer, 2010; Wouter, Paas & Van Merrienboer, 2008) can be as good as an animation for fostering comprehension.

In contrast with previous studies, the present research explores the potential of dynamic visual displays, not to help comprehension in an educational end, but to promptly trigger in the traveler's mind a task-appropriate script of the relevant events. When travelers are under extreme time pressure to catch their trains, the bottom-up features of the information they receive from an external representation (in this case, visualizations) should perfectly map to top-down aspects of their existing internal representations. By this reasoning, if travelers' mental scripts for railway disruption situations themselves have key dynamic dimensions, then it could be expected that a dynamic presentation with animations of the events involved would allow a more efficient and effective match to the corresponding internal representations than would a static presentation. Therefore, the advantage that animation could have over static picture, in the case of public information, would not be so much in showing the microsteps of the dynamic process (that could be shown with series of static pictures as well). But, in the train announcements, animation could work as quickly clarifying a dynamic concept (or event), like the train that 'arrives' at a platform, a platform that 'changes', and travelers having to 'move' from one platform to another platform. The dynamic presentation would have a positive effect on comprehension if these dynamic concepts are not well understood from static pictures. A key issue in train announcements consists in understanding what is going on and knowing what to do. Travelers may not recognize so easily the dynamic events when they are displayed as static pictures.

1.3. Animation and presentation regime: sequential or simultaneous?

In the context of animation research, much previous experiments comparing animated with static graphics has set a continuous animation of the dynamic process against series of static pictures (for example, Arguel & Jamet, 2009; Bétrancourt, 2005; Boucheix & Schneider, 2009; Hasler, Kersten, & Sweller, 2007; Höffler & Leutner 2007; Imhof, Scheiter & Gerjets, 2011; Imhof, Scheiter, Edeleman & Gerjets, 2012; Kim, Yoon, Whang, Tversky & Morrison, 2007; Kriz & Hegarty, 2007; Lowe & Schnotz, 2008; Lowe, Schnotz & Rasch, 2010; Mayer, Hegarty, Mayer & Campbell, 2005). With a few exceptions (e.g., Lowe, Schnotz & Rasch, 2010), typically, the series of static pictures is derived from the animation by extracting single frames that show only the main steps of the dynamic content (e.g., key frames). This extraction inevitably reduces the amount of the information available compared with that in the full animation format.

Depending on the study, these sets of static pictures are usually presented to the participant in two possible delivery regimes: *sequential* or *simultaneous*. With the sequential regime, two variants can occur (i) *replacement* in which each of the pictures is delivered to the same spatial location in order, one picture after another - the first frame disappears when the second appears, and so forth. Under such circumstances, the new information may override the predecessor information in working memory. Further, there may be interference with the perception of continuity of movements (Lowe, Schnotz & Rasch, 2010) and increased cognitive demands because the learner must maintain the first picture in working memory while the second is processed (Ayres & Paas, 2007; Lowe, 1999; Paas, Van Gerven & Wouters, 2007). (ii) *Addition* in which the static pictures appear sequentially but are retained (each on its own piece of screen real estate) once they have been presented so that the set of pictures is built up progressively. This approach was used in the present study because it avoids some of the processing challenges associated with replacement.

With the simultaneous regime, all pictures in the set are delivered to adjacent locations on the screen at exactly at the same moment. Because the full set of pictures is accessible at once, the learner has the opportunity from the outset to perform direct visual comparisons between different steps of the depicted process. However, simultaneous presentation does not provide the temporal staging effect that is available with sequential presentations. As a result, viewers receive no explicit guidance as to the order in which pictures should be inspected. They could however invoke knowledge of reading direction conventions to navigate through the picture set. However, this format could provoke in an initial searching activity which induces undesirable delays in situation where there is time pressure (as can be the case for rail travelers).

Although previous research has used both sequential and simultaneous presentations for static graphics (see for example, Boucheix & Schneider, 2009; Imhof, Scheiter & Gerjets, 2011;

Imhof, Schieter, Edeleman & Gerjets, 2012; Kim, Yoon, Whang, Tversky & Morrison, 2007; Lowe, Schnotz & Rasch, 2010), animations are usually presented in only the sequential modality. In such presentations, each new frame is an alteration of the previous frame, so that in most studies, sequentiality of the presentation is therefore inevitably confounded with animation of the display's components.

This is an important issue because recent research indicates that sequential and simultaneous presentations are anything but equivalent and could result in significant differences in task performance. The few studies that have been conducted on sequentiality with static visualizations have led to inconsistent results. For example, in the case static graphics depicting steps in the functioning of a three pulley system, Boucheix & Schneider (2009) found superior comprehension for simultaneous presentation of a five-picture series than for their sequential presentation. More recently, in a fish locomotion pattern classification task from visualizations, Imhof & al., (2011, 2012) found the similar results, with participants in an animated condition outperforming those using nine static sequential pictures. However, participants in the static simultaneous condition (a row format) had the same performance as participants in the animated condition. In contrast, the study with six graders on the understanding of a bicycle pump by Kim & al. (2007) showed that static simultaneous visualizations led to lower comprehension scores than animated and static-sequential visualizations. Further, in a task where learners were required to arrange kangaroo hopping pictures into the correct order, Lowe, Schnotz & Rasch (2010) found that a static sequential presentation of the learning material was better than an animated and or a static simultaneous presentation. In the case of animated graphics, a recent study by Morand & Bétrancourt (2010) was designed to prevent confounding of animation and sequentiality. A traditional sequential animated presentation of meiosis was compared with a simultaneous animated version in which small animated segments of the process were delivered simultaneously spread across a screen. It was found that transfer task performance of participants given the simultaneous animation was superior to that of those in the sequential condition.

More generally, Lowe, Schnotz & Rasch (2010) showed that aligning affordances of the graphics with the task requirements could be an important aspect of visualization design. This means that here, outside of the educational animation field, graphic presentation should be aligned on the structure of the traveler's internal scripts of the train disruptions, in order to map with them. These scripts, as the announcement texts for the most common disruption-related loudspeaker messages, are structured as an ordered (and chronological) sequence. When watching the visual announcements, travelers will use their mental scripts (that are based upon the structure of these loudspeaker messages). Consequently a sequential presentation of pictures would allow a more efficient and effective match to the corresponding internal representations than would a simultaneous presentation.

1.4. Present study and hypotheses

In the present study, four purely graphic presentation conditions were used to deliver train disruption messages: animated sequential (AnSeq), animated simultaneous (AnSim), static sequential (StaSeq), and static simultaneous (StaSim).

This experiment was a crucial part of a broader project composed of a program of experiments which intended to address separately different issues of the comprehension processes of train disruption messages.

A first issue concerned the intended population: all travelers in train stations, and particularly, travelers with hearing impairment and old persons. Regarding this point, experiments had previously been conducted with small samples of hearing impaired and elderly people (see Boucheix, Lowe, Paire-Ficout, Saby, Alauzet,Conte, Groff &, Argon, 2010; Paire-Ficout, Saby, Alauzet, Groff & Boucheix, 2013). In those studies, only three presentation conditions were compared; animated sequential, static sequential and static simultaneous. The results, for these two samples, indicated that comprehension was higher with animated than with static presentation. There was also some indication of an advantage for sequential presentation. Another experiment is currently in progress with different category of hearing impairments.

A second important issue is about the speed of comprehension of the messages in the context of railway stations. Indeed, travelers have sometimes to catch a train under time pressure, in other word the ecological value of the experiment. A future experiment is planned yet in a more "real" train station context (using virtual reality) in which manipulation of time on task and starting point of visual information will be examined.

The present study addressed another crucial issue related to the comprehension processes of every part of the pictographic information within each message. For that reason, in the experiment was used a controlled comprehension task in which participants were given the same information and the same controlled amount of time (thus allowing them to have enough time) to process all the pictographs. The main issue was: is the whole pictographic message understood and how, depending of the experimental conditions? Such investigation was required given the general aim of the study about using animation to make people understand a dynamic situation and how to convey train announcements in a series of visual pictographs.

The goals of the present study were therefore: (i) to make a more refined and comprehensive comparison of the effect of different graphic message conditions formats on comprehension, by teasing out the individual contributions of graphic format (animated versus static) and delivery regime (sequential versus simultaneous); (ii) to investigate underlying cognitive processing reasons for the differences in comprehension of public information displays that employ different graphic formats and display regimes using eye tracking techniques; (iii) to study a larger and less restricted sample of participants; and (iv) to examine the comprehension of each part of the message given that each participant processed every part of the information delivered by the message.

Our prediction was that a sequentially presented animated condition would be of most help to participants in following the course of depicted events and mapping that information to relevant script schemas in long term memory. More specifically, in the case of the train messages, the sequential animation is most consistent with how internal scripts are likely to be organized with respect to spatiotemporal information. It was therefore expected that (i) *Hypothesis 1,* comprehension performance for the sequential presentation regime would be superior to that for the simultaneous presentation regimes and (ii) *Hypothesis 2*, comprehension performance for animated format would be superior to that for static format. As a consequence of expected both main effects, the optimal condition would be when the animated format is presented sequentially.

1.5. Eye tracking for online investigation of graphic comprehension processes

A growing body of research has used eye tracking to study comprehension of, or learning from, multimedia presentations (including animations). Most of these investigations have dealt with text-picture combinations, Canham & Hegarty, 2010; Jarodzka, Scheiter, Gerjets & Van Gog, 2010; Meyer, Rash, & Schnotz, 2010; Schmitt-Weigand, Kohnert & Glovella, 2010; Van Gog & Scheiter, 2010. Less research has been conducted on animated graphics presented without accompanying text (Boucheix & Lowe, 2010; Boucheix, Lowe, Putri & Groff, 2013; De Koning, Tabbers, Rikers & Paas, 2010; Lowe & Boucheix, 2011; Scheiter &

Eitel, 2010) and to our knowledge almost no experimental studies (Zwaga & al., 1999) has addressed public transport information.

Because the research reported here investigated not only static graphics but also their animated counterparts, our use of eye tracking extended beyond measuring just total viewing durations (dwell time). In addition to total viewing duration in Areas of Interest (AOIs), we used eye tracking to investigate how the different presentation conditions may influence attention direction during visual search of the messages, particularly the order in which the graphic material constituting each message was processed for the various message versions. For this purpose, we determined the number of fixations participants made before attention (first fixation) arrived on the nominated target either a whole frame or an entity within a frame. For this measure, taking only strict raw data into account may result of 20 ms glances on an AOI that would be not meaningful. So, we used a minimal amount of time spent on AOI based on raw data with a fixation definition of 100ms. This measure was termed the pre-target count and could apply either to a whole picture or to a specific graphic component within a picture.

Different eye movement patterns were expected for each of the four presentation conditions. More specifically, for the animated sequential condition, it was expected that, (i) *Hypothesis 3*, the *pre-target count* for each of the four pictures comprising a message would strongly reflect the onset order of the pictures. This is because the dynamic unfolding of the animated sequential condition would exert a powerful influence on viewers' attention resulting in them closely following the sequence of events. This 'following' behavior (c.f. Lowe, Schnotz & Rasch, 2010) was expected to happen not only *across* the series of four pictures (see figure 1) but also *within* each picture where animated components (train, platform letters, arrows, etc.) could also appear sequentially. For example, in picture two of Figure 1 (animated sequential version), the train moved before the platform letter was crossed out. Our expectation was that the pre-target count for picture components would reflect such appearance orders.

For the static sequential condition, it was expected that (ii), *Hypothesis 4*, the pre-target count would also strongly reflect the picture onset order. However, close following behavior was expected only across pictures because within-picture components all appear at the same time.

For the static simultaneous condition, it was expected that (iii) *Hypothesis 5*, the pre-target count for each picture would not reflect the order of the pictures as strongly because their sequencing was only spatial rather than also being temporal. In the absence of any temporal influence on attention direction, there would be less coordination with the events schema both across and within pictures. Such less ordered searching behavior, not coordinated with the script of the events depicted by the pictures, would apply across pictures as well as inside pictures.

For the animated simultaneous condition, it was also expected that (iv), *Hypothesis 6*, although pre-target counts for within-picture components would reflect the order in which they appeared, there would be much less correspondence between pre-target counts for the whole pictures and their spatial ordering.

Regarding the total viewing time for each picture it was expected that (v), *Hypothesis* 7, participants would spend more time on the pictures depicting the cause and effect (main events, pictures 2 and 4) of the disruption message than on the pictures showing the warning and the recommended action (pictures 1 and 4). Time spent on the familiar warning (picture 1) would be relatively short (essentially involving recognition only) because it is a widely used, standardized symbol that can be processed holistically. The cause and effect pictures (2 and 3) are specific to the railway context and differ according to the particular situation being represented so viewer processing should take longer. However, once interpreted, they trigger a relevant event schema that includes a likely response. Picture 4 therefore serves a mainly confirmatory function so less processing time is needed.

2. Method

2.1. Participants

A total of 86 undergraduate students (psychology and education areas, 13 males and 73 females) took part in the study for course credit. Participants were all native French speakers with normal vision accuracy, (*M* = 19, 25 years, *SD* = 2, 54). Before the experiment, participants completed a multiple choice question on how frequently they caught a train: *"at least one time a week, at least one time a month, at least one time a year, or never"*. These four levels of train use assessed with the multiple choice question were scored from 4 points (*one time a week*) to 1 point (*never*). Participants with 4 and 3 points were assigned to a frequent user category; participants with 2 and 1 points were assigned to an infrequent user category. Participants were randomly assigned to the four presentation format groups as follows: animated sequential (AnSeq) n= 22; animated simultaneous (AnSim), n = 20; static sequential (StaSeq), n = 22; static simultaneous (StaSim), n = 21.

Materials and experimental design

Five graphic-only train messages (figure 2) were developed for (a) a platform switch, (b) a train delay, (c) a train cancellation (d) a nonstop high speed train, passing, and (e) a strike. Each message used a set of 4 pictures to depict the information normally given by a standardized loudspeaker announcement.

Insert Figure 2 about here

All messages shared the same four-stage structure: a warning (picture 1); a reason for, or cause of, the disruption (picture 2), the effects of the disruption (picture 3), and the action travelers should take (picture 4). The graphic constituents of the pictures and their visual treatments were consistent with those long used in French National Railways signage so they were already very familiar to most travelers (see Nakamura & Zeng-Treitler, 2012; Zwaga, & al., 1999).

The experimental design had presentation format (animated *vs.* static) and presentation regime (sequential *vs.* simultaneous) as two between subjects factors and message type as a within subject factor. The frequency of railway use was a control factor with a X^2 test establishing that there was no significant difference in the distribution of high and low frequency users across the four conditions of presentations, X^2 (3) = 1.62, $p > .60$.

In the static simultaneous condition, the four static pictures and their internal components all appeared on the computer screen at the same time (as in figures 1 and 2). In the static sequential condition, each static picture and all its internal components appeared one at a time with the row of pictures being built up from left to right. The animated sequential condition was similar to the static sequential condition except that in the animated condition, the internal components of each sequentially presented picture were (sequentially) animated instead of static (see the example in the Appendix A).

The same internal component animations were present in the animated simultaneous condition, but all four pictures in the set were presented at once instead of successively. Given the pure comprehension goal of the study, all messages used had the same total duration of eleven seconds. In the sequential regimes, for each message, a new picture (out of the 4) appeared every 2.75 seconds and, once exposed, persisted until the end of the message duration (total: 11 sec.). In summary then, the presentation proceeded as follow: (i) onset time: 0 sec., picture 1 warning; (ii) onset: 2.75 sec., picture 2; (iii) onset: 5.5 sec., picture 3; (iv) onset, 8.5 sec., picture 4. This presentation rhythm was favored because on one hand it should give each participant the opportunity to process the pictographic information completely and on the other hand the duration was not too long; even if all participants will not always start watching at the beginning of the sequence. This last point could be assessed by eye movements' behavior analyses.

In the animated sequential condition, for one delivery of the message, every time a picture appeared, each animated component within the picture was sequentially animated one time only before the appearance of the first animated component of the next picture (see Appendix). Because of the strict sequentiality of the onset of each animated component, the opportunity for the learners to view each animation was high in this presentation condition.

In the animated simultaneous condition, because the four pictures in the set were presented at once instead of successively, the onset of every animated component within each picture began simultaneously. In such condition, the opportunity of noticing and viewing each animated component before the end of the movement of the component was lower compared to the animated sequential format. In order to control this potential problem, and to give participants more comparable opportunities to truly perceive and view the animation of the components in a similar way in the two animated conditions, in the animated simultaneous condition, each animated component within the picture was animated three times (within the duration limits of the message), instead of one time only as in the animated sequential condition. The fine-tuning adjustment of this design was realized in a previous pilot study (with 2 groups of 20 participants different from the participants used in the present study).

In sum, the four conditions from the two factors, presentation format (animated versus static) and presentation regime (sequential versus simultaneous) scaled four levels of dynamism: (i) AnSeq was the highest level in which both objects of the episodes and the episodes themselves were respectively animated and sequentially presented;(ii) StaSeq was a medium-plus level in which the objects (less salient dynamic contrast) were static while the episodes (more salient dynamic contrast) were dynamic; (iii) AnSim was a medium-minus level in which the objects were animated while the episodes were simultaneously presented and (iv) finally, StaSim was the lowest level of dynamism in which both objects and episodes were static.

Apparatus

The messages were presented on a 17 inch TFT monitor having a resolution of 1024 x 728. Participant eye movement data were collected by a Tobii 120 binocular Eye Tracker (with Tobii Sudio software). By default, the Tobii defines a fixation as one or more gaze points within a circular area of 30 pixels for a minimum duration of 100 ms. However, in this study, for the duration measure (see hypothesis 7) we instead used a dwell time measure based on raw eye movement data (Hyönä, Radach & Deubel, 2003). This is because when looking at dynamic stimuli like animations, smooth pursuit eye movements may occur (see for example, Jarodzka, & al., 2010) and these are undetectable with current eye tracking software. A microphone connected to the computer and synchronized with the eye tracker recorded participants' spoken answers (see procedure).

Task and Comprehension test measure

Participants were asked to imagine they were in a railway station preparing to catch a train. They were then told to look at the messages carefully in order to understand them. The five messages were presented in random order one at a time for 11 seconds, with each message being displayed two times in succession. Prior to the onset of each message, a black fixation cross appeared in the middle of the screen to direct attention to a reference location.

Immediately after the message had finished, the participant was asked to give the meanings of both the message as a whole and of its constituent pictures. Participants could give additional information after the second presentation of each message. The message display began when the participant pressed a computer key. For the sequential condition, the time intervals between presentations of the successive pictures comprising the message were exactly the same.

Participants had to give the meaning of each message immediately after the end of the message but no additional time was separating the end of the message and the beginning of the response of each participant. The message was presented twice. So, this procedure was not a demanding recalling task. Why not testing more directly online comprehension of the graphics, which would be also a valuable method in such investigation? There were three reasons for choosing a more conventional comprehension test in this study. (i) for control purposes in this particular experiment, it was required that all participants were exposed to each message during the same amount of time as well as for the same amount of information in the message. This "safety measure" prevented participants from completely neglecting one part of the message if they had understood the meaning of the message yet before its ending. (ii) our comprehension test was not too far from real conditions in railway stations. Once a traveler has heard the message from the loudspeaker (or seen the message from the computer screen), then he usually has to move from the main hall to the right platform, or from one platform to another. During this moving time he has usually to take (underground) stairs, or to cross long corridors without hearing or seeing anymore the message. So, during this moving time, it is quite crucial for every traveler to maintain the information in working memory and to remember it while moving in the station to go to a new platform (and sometimes detail information such as the number of the platform or the number of the train). One can easily imagine what could happen if, when crossing an underground corridor to reach a platform, the traveler has forgotten the content of the message about the platform change! (iii) it is true that having participants answer the questions with the graphics present would provide an estimate of the time it took them to comprehend the message. This would be very valuable information given the practical goal of the study. This was exactly the goal of a further more "ecological" study planned in the overall project evoked earlier (see also the discussion section).

Transcribed answers were coded according to a fine grain scoring grid designed for each message and that awarded up to two points for each individual picture in the message set, according to its specific contents. Using this system, the maximum possible score for the train cancellation message (more graphic components) was six points and five points for each of the remaining messages (Appendix B). Participant's answers were rated by two independent raters, inter-rater agreement, chance corrected Cohen's Kappa was .95. Scores on each message were transformed into ratio.

Eye tracking data analysis

Two sets of AOIs (Areas Of Interest) were designed to account for either each picture as a whole (picture AOIs), or individual components within a picture (component AOIs). As shown in figure 3, there were four picture AOIs and these were the same for all 5 messages.

Insert Figure 3 about here

However, more component AOIs were required for each message in order to account for onset of the picture's internal components and their dynamics in the animated versions. The eight such AOIs used for each message did not include the initial warning picture which merely flashed on and off. The platform switch example (figure 4) illustrates how component AOIs were allocated. In this case, there were two AOIs for the second picture, (train and platform components), three AOIs for the third picture (train, platforms and arrow) and three AOIs for the last picture (the character, and two platform-stair-arrow combinations). This AOI distribution across components (2 AOIs for the second picture, 3 AOIs for the third picture and 3 AOIs for the last picture) was the same for the five messages.

Insert Figure 4 about here

To address hypotheses 3, 4, 5 and 6, picture AOIs were used to study processing of each message as a whole (i.e., warning-cause-effect-action). The component AOIs were used for more detailed investigation of how the animated components within individual pictures were processed. The two dependent measures referred to above (pre-target count and total viewing duration) were used for both picture and component AOIs.

Procedure

Participants were tested individually in a single session. On arrival, information about the study was provided and participants completed the train use questionnaire. Next, the participant's eye movements were calibrated automatically by Tobii's studio software using nine fixation points (and later recalibrated if necessary throughout the session). Then, the comprehension task for each message took place.

2.2.2. Results

Comprehension measures

Table 1 presents the mean comprehension scores (percentages) for the messages in their different conditions.

Insert Table 1 about here

To examine hypotheses 1 and 2, a 2x2 MANCOVA was conducted with presentation regime (sequential vs. simultaneous) and graphic format (animated *vs.* static) as two between subjects factors and message type as within subject factor. Because the train use measure could be considered as an indirect but reliable indicator of the quality of the internal script available from long term memory, this controlled factor was used a covariate. Analyses were performed with "Statistica 10" software, which computes automatically MANOVA tests (General Linear Models of MANOVA/MANCOVA).

This analysis revealed a significant main effect on comprehension of presentation regime, F (1, 81) = 7.84, p =.006, η^2 = .09, with the sequential regime (M = 57.5) being superior to the simultaneous regime (M = 47.25). The animated format appeared better (M = 54.1) than the static format (M = 50.6), but the difference was not significant, F (1, 81) = 1.30, p = .26, η^2 = .01. The effect of the type of message was significant, F (4, 324) = 10.03, p < .001, η^2 = .12. Comprehension was high for the platform switch, train cancellation, and train delay messages, medium for the nonstop high speed train message, and lower for the strike message.

Frequency of railway use had also a significant effect, F (1, 81) = 11.27, p = .001, η^2 = .12, with frequent train users (M = 56.87, N = 59, SD = 15.90) having better comprehension scores than those who used trains infrequently (M = 43.28, N = 27, SD = 13.76). The correlation between comprehension performances (mean percent, all messages) and train user frequency was significant, *rs (86) = .39, p=* .0002. *(.42, p = .00004).*

The interaction between graphic format and presentation regime was not significant, F (1, 81) = .01, p = .93.

There was a significant interaction between train use and message type, with the spread of comprehension scores across the different types of messages being greater for infrequent users than for frequent users, F(4, 324) = 3.23, p = .013, η^2 = .04. There was also an interaction between message types and regime, F(4,324) = 2.69, p = .031, η^2 = .03; showing that the sequential regime was better than the simultaneous regime for 4 out of the 5 messages except for the message about the strike which was not well understood whatever the presentation conditions. No other interaction was found significant.

In summary, comprehension scores in sequential presentation regime were superior to those in simultaneous presentation regime, but there was no difference between the animated graphic format and the static graphic format.

Eye movement data

Because separate analysis of eye movement data for the first and the second exposures of each message gave very similar results, only data from the first exposure are presented here.

Picture AOIs

Table 2 shows the mean (a) pre-target counts, with the number of fixations before the arrival of the first fixation in each of the four AOIs and (b) total viewing durations in seconds for each of the four picture AOIs (across the five messages).

Insert Table 2 about here

The pre-target counts for the picture AOIs shown in table 2 suggest important differences between the two presentation regimes. As predicted, (hypotheses 3 and 4) the pre-target counts for both the animated sequential and static sequential conditions increase relatively regularly through the time course of the message exposure. Participants tended to follow systematically the linear left-to-right order of pictures in the set. The pattern of eye movement for the two simultaneous presentation conditions was different from the two sequential conditions in some key ways. Consistent with hypotheses 5 and 6, participants did not follow the strict linear order of the message, with the picture 1-2 pre-target counts being greater than the picture 2-3 pre-target counts. In these versions, spatial location of AOIs 2 and 3 (middle position) and perceptual saliency of the pictures could be also influential. Further, the pre-target counts tended to be less than half of those for the simultaneous conditions. Those observations were confirmed statistically performing a 2x2 MANOVA on the pre-target count data, with (i) sequential versus simultaneous regime and animated versus static presentation format as two between subjects factors and (ii) AOIs as the within subject factor. Message type was not included in this analysis because there was no precise hypothesis about eye movements regarding this factor. The results of the MANOVA revealed a significant effect of the regime, $F\,(1, 81) = 12.70$, $p = .0006$, $\eta^2 = .13$; no effect of the presentation format (Animated *vs.* Static), $F\,(1,81) = 0.06$, $p = .80$, $\eta^2 = .0007$; and a strong effect of the AOIs, $F\,(3, 243) = 213.52$, $p < .0001$, $\eta^2 = .72$. There was also a significant interaction between regime and AOIs, $F\,(3, 243) = 99.92$, $p < .0001$, $\eta^2 = .55$.

Table 2 indicates also variations in the total viewing duration with AOI across the different experimental conditions. Consistent with hypothesis 7, pictures 2 and 3 received more attention than pictures 1 and 4. Participants in the sequential regime spent more time on picture 2 than on picture 3, while with those in the simultaneous regime this situation was reversed. A repeated MANOVA performed on the viewing duration data with (i) sequential versus simultaneous regime and animated versus static presentation format as two between subjects factors (ii) AOIs as the within factor indicated a significant effect on total viewing duration of presentation regime $F(1, 81) = 7.44$, $p < .008$, $\eta^2 = .08$ (with *M* AnSeq = 9.80 sec.; *M* StaSeq = 9.77 sec.; *M* AnSim = 10.45 sec.; *M* StaSim = 10.29 sec.); but no effect of the presentation format, (Animated *vs.* Static), $F(1, 81) = 0.18$, $p = .66$, $\eta^2 = .002$. As expected, there was a main strong significant effect of AOIs, $F(3, 243) = 443.54$, $p < .0001$, $\eta^2 = .84$. Finally, the regime * AOIs interaction was significant, $F(3, 243) = 65.52$, $p < .0001$, $\eta^2 = .45$.

Picture components 8 AOIs analysis

Table 3 shows the mean (a) pre-target counts, and (b) total viewing durations in seconds for each of the eight component AOIs.

Insert Table 3 about here

The pre-target counts for the component AOIs add interesting details to the broader pattern of results found for the picture AOIs. The finer component-based analysis revealed differences between the animated sequential and static sequential conditions and also between the two simultaneous conditions. As predicted (hypothesis 3), the pre-target counts for the animated sequential condition increased relatively regularly through the time course of the message exposure. Contrary to what was expected from hypothesis 4, this global pattern of following the message structure seemed similar for the static sequential conditions, with slight variations for AOIs 3-4 and 7-8. However, the pattern of pre-target counts was considerably less regular for the simultaneous conditions with decreases rather than increases occurring for a number of successive AOIs.

A 2x2 MANOVA performed on the pre-target counts, with (i) sequential versus simultaneous regime and animated versus static presentation format as two between subjects factors and (ii) AOIs as the within subject factor, confirmed but also extended these observations. First, a significant effect of both presentation regime (F (1, 81) = 86.13, $p < .0001$, $\eta^2 = .51$) and presentation format - animated vs. static- (F (1, 81) = 4.46, $p = .038$, $\eta^2 = .05$) was found. These effects showed participants in the sequential regime making much more pre target fixations in AOIs than participants in the simultaneous regime, but also participants in the animated format making less pre-target fixations in AOIs than participants in the static format. However, the effect of regime (across pictures contrast) seemed to be more powerful that the effect of animation (within picture contrast). Further, as expected, the number of pre target fixations increased greatly from AOI 1 to AOI 8, F (7, 567) = 133.43, $p < .0001$, $\eta^2 = .62$, which suggests again a “following” strategy. In line with hypothesis 3, 4, 5 and 6, this increasing effect was significantly higher and far more linear for the sequential regime than for the simultaneous regime.

Two interactions were found significant (i) the interaction between the presentation regime and the AOIs, F (7, 567) = 9.25, $p < .0001$, $\eta^2 = .10$; (ii) the interaction between the presentation formats (animated *vs.* static) and the AOIs, F (7, 567) = 2.70, $p = .009$, $\eta^2 = .03$.

For the total viewing duration in AOIs across the different presentation conditions, the overall trend is for a progressive decrease from AOI 1 to AOI 8 (table 3) but with trend being much more pronounced for sequential than for simultaneous regime. A repeated MANOVA was performed on the viewing duration data with (i) presentation format (Animated vs. Static) and presentation regime (Sequential vs. Simultaneous) as two between subjects factors and (ii)

AOIs as the within subject factor. There was a significant effect of the presentation format, F (1, 81) = 5.9, $p < .017$, $\eta^2 = .07$, with participants spending more time on the animated format than on the static format. There was an effect of the presentation regime, F (1, 81) = 16.28, $p = .0001$, $\eta^2 = .17$, with participants spending more time on each AOI in the two simultaneous conditions than in the two sequential conditions. There was also a significant effect of AOIs, F (7, 567) = 123.37, $p < .0001$, $\eta^2 = .60$.

The significant interaction between presentation regime and AOIs, F (7, 567) = 11.47, $p < .0001$, $\eta^2 = .16$, indicated that the patterns of viewing durations across AOI 1 to AOI 8 were different for the sequential and simultaneous regimes. Viewing durations decreased significantly earlier and more consistently for the sequential regime than for the simultaneous regime.

3. Discussion and conclusion

This research investigated the comprehension of computer screen animated public information graphics about train disruption messages in railway stations. Manipulating two presentation factors, sequentiality and animation, four visual presentation conditions, alternatives to traditional spoken announcements, were compared: animated sequential, animated simultaneous, static sequential and static simultaneous. In the approach followed in this paper, animations were used to explore the potential of dynamic visual displays, not only to help comprehension, but to quickly and effectively trigger a task-appropriate script of the relevant dynamic events. A key issue in using visualizations for the purpose of train disruption messages was the extent to which bottom-up features of the external depiction map to top-down aspects of existing internal representations. If long term scripts of (railway) transport disruptions events are chronological ordered and dynamic stored schemas, then, it can be expected that a sequential dynamic presentation with animations of these events would match more quickly and efficiently than a simultaneous and static presentation the corresponding internal representations. Complementary to comprehension performance measures, online comprehension processes were investigated by using eye tracking measures. In this section we will discuss firstly comprehension results relatively to hypotheses 1 and 2, and secondly the eye movements data in relation with hypotheses 3 to 7. Finally some limitations to the study will be brought before a short overall conclusion.

In line with *hypothesis 1 prediction,* higher comprehension performance for the sequential regimes than for the simultaneous regimes was observed. However, contrary to *hypothesis 2,* the predicted superiority of the animation over the static did not really eventuate; comprehension performance for animated format was not superior to that for static format. The sequentiality of the presentation of the pictures seemed to be the crucial factor in the comprehension performance results. Indeed, the four conditions from the two factors, presentation regime (sequential versus simultaneous) and presentation format (animated versus static) scaled four levels of dynamism: (i) AnSeq was the highest level in which both objects of the episodes and the episodes themselves were respectively animated and sequentially presented;(ii) SatSeq was the medium-plus level in which the objects (less salient dynamic contrast) were static while the episodes (more salient dynamic contrast) were dynamic; (iii) AnSim was the medium-minus level in which the objects were animated while the episodes were simultaneously presented and (iv) finally, StaSim was the lowest level of dynamism in which both objects and episodes were static. In relation with this scaling, results showed that the two first levels which emphasized the dynamism of episodes (regime) rather than the dynamism of components (format) were the most influential in comprehension.

Two non-exclusives explanations could be proposed for explaining these comprehension results. (i) Firstly, if internal scripts are structured in terms of a fixed temporal order of episodes corresponding to events slots such as a reason of the disruption (because of the working on track, of the weather…etc.); a coherent set of events, which is the effect of the disruption, (changes of platform, delay, cancellation etc.) and an action to take (move from one platform to another, check the central panel, ask to information desk; waiting, etc.), then it could be proposed that what matters for an external presentation to mapping the internal script, is the sequentiality of the episodes rather than the dynamism of the components within the episode. In other words, these results suggest that what matters really in train disruption messages is a coherent set of pictographs forming an episode rather than the animation of each component. And may be, when a traveler faces a familiar individual component, a motion feature could be automatically (and implicitly) triggered by the static picture (a train moves, or passes, the rain is falling down from a cloud, etc.). Further, the effect of sequentiality may not be limited the sequentiality across pictures, that is to say across episodes, but could also apply to the sequentiality of the occurrence of the components within each picture, that is to say within the episode. These results also extend the approach by Nakamura & Zeng-Teitler (2012) in showing the possible effectiveness of a series of pictographs for the delivery of meanings which are more complex than those commonly transmitted through the most conventional use of single pictographs.

Regarding design decisions relatively to the choice between sequential or simultaneous presentation, our results are perfectly in line with the statements which conclude the study by Lowe, Schnotz & Rasch (2010) showing that aligning affordances of the graphics with the task requirements could be an important aspect of visualization design. This means that here, graphic presentation should be aligned on the structure of the traveler's internal scripts of the train disruptions, in order to map with them. These scripts, as the announcement texts for the most common disruption-related loudspeaker messages, are structured as a chronological sequence of episodes. When watching the visual announcements, travelers used their mental scripts (that are based upon the structure of these loudspeaker messages). Consequently as expected, the sequential presentation of episodes allowed a more efficient and effective match to the corresponding internal representations than did a simultaneous presentation.

(ii) The effect of regime was significant in comprehension while the effect of animation did not. This result could give rise to a new hypothesis which could be related to the way animated and static graphics are commonly conceptualized in most previous approach. This conceptualization is often reduced to a “coarse” temporal aspect of animation delivery: their transience. However, animation can also be conceptualized at more functional level, which refers more precisely to the type of dynamics that are conveyed in the external representation, Lowe, 1999, 2003. According to this level of analysis, animations can convey three main types of changes. Transitions are inclusion changes which involve the appearance (or disappearance) of full entities, such as a new picture added to a previous one. Translations are position changes involving the movement of entities from one location to another. Transformations are form changes, involving alteration of graphic properties (size, shape, color and texture). In the four formats tested in the present study, the two sequential presentations are indeed examples of transition, with whole pictures appearing one by one, each representing a coherent set of events (an episode). The animations within pictures contain translations (trains move) and transformations (arrows grow).The (perceptual) dynamic contrast produced by transitions across pictures seems higher than the contrast produced by the little transitions and transformations that occur within pictures.

This superiority of the dynamic contrast of transition across pictures over the contrast produced by smaller transitions and transformations within pictures could have an effect on the extraction of the meaning of the message in favor of the sequential regime.

In sum, it is indeed the sequential nature of the display that is most important for processing and comprehension, not simply whether the components within the pictures are animated or static. The superiority of the sequential presentations over the simultaneous ones could arise from the nature of the visual interrogation that is performed progressively picture after picture, and the fit or the affordance of the presentation format of the message with the format of existing event schemas.

Regarding these eye movements' results, respectively for the four picture AOIs and for the eight components AOIs processing, two remarkable points, came up from (i) pre-target counts and (ii) viewing time data.

(i) With pre-target counts, as expected with *hypothesis 3 and 5*, for the sequential conditions, eye movement data showed the pre-target counts on each of the four pictures followed the time order of the onset of each picture of the series. This "following" behavior tended to happen not only across pictures but also within pictures across the components. The tendency to "follow" the onset of the components within pictures was more marked in the animated sequential condition than in the static sequential condition (table 3).

As predicted by *hypothesis 5 and 6*, in the case of the simultaneous conditions, pre-target counts on each AOI did not follow strictly the order of the pictures, and an additional visual searching time occurred. Such unordered searching behavior, was not aligned with the script of the events depicted across the pictures. However, hypothesis 6 was partially confirmed for the animated simultaneous condition. A relative unordered searching behavior was found across pictures, but inside each picture viewing direction did not exactly followed the order of the onset of the components.

(ii) Regarding viewing time, for the sequential regimes, we found a strong significant and regular decrease of the viewing time from the first AOIs to the last AOI. There was not such acute decrease of the viewing time from the first AOI to the last one in the simultaneous conditions. In the four AOIs analysis, except the warning sign AOI 1, the means of fixation duration in each of the three AOIs were respectively for the sequential regime AOI 2 (cause) = 3.82 sec., AOI 3 (main event) = 2.98 sec., AOI4 (action to take) = 1.62 sec.; and for the simultaneous regime AOI 2 (cause) = 3.17, AOI 3 (main event) = 4.16, AOI 4 (action to take) = 2.38.

Again, as for comprehension results, and for the pictures 4 AOIs analysis, only the effect of regime was significant, the effect of presentation format was not. For the picture components 8 AOIs analysis both regime and format (animated versus static) were found significant for pre-target fixations and fixation duration. In the sequential regime participants arrived later than in the simultaneous regime in the AOIs but they spent less time in pictures and on their components than in the simultaneous regime. Further, participants in the animated conditions arrived sooner on the components of the pictures than participants in the static conditions and they spent more time on the components than participants in the static conditions.

Overall, the eye tracking data mainly showed that participants follow the dynamics of elements appearing: in the sequential conditions, their gaze follows the picture-by-picture presentation, whereas in the animated conditions, their gaze follows the picture components that appear one-by-one, and one after the other. That means that participant's gaze is attracted to newly appearing information, or put differently, that if people all information is shown to the individual (simultaneous: all pictures; static: all picture components) they tend to look to information that is hidden in the other conditions.

Further, following our previous line of reasoning in terms of stronger dynamic contrast of transition across pictures than the contrast produced by smaller transitions and transformations within pictures, these dynamic contrast differences could be an explanation for the "following" behavior, which seems to be efficient for comprehension of public information. May be, because internal translations and transformations within pictures involved less dynamic contrast than transitions between frames, it resulted in a weaker "following" behavior within picture frames. The sequential regime seems to favor a progressive serial processing of the message while simultaneous regime seems to favor a parallel processing, less progressive.

The quick and continuous decrease of fixation duration across the four pictures (and 8 components) AOIs in the sequential presentation suggests clearly the efficient mapping process between the external presentation and the internal script of the disruption message. After the short note of the warning sign by participants, the processing of the first picture, describing the cause or introducing the main disruption event, very quickly and effectively trigger the task-appropriate script of the relevant dynamic events. In the case of sequential presentation, initial bottom-up features of the external depiction seem to perfectly map to top-down aspects of existing, ready structured internal representations

Finally, as predicted in *hypothesis* 7, participants spent more time on the pictures depicting the cause and the effect mains events of the disruption messages than on the warning and on the recommended action pictures. For the sequential regimes, the time spent on the picture 2 (the cause of the disruption) facilitated the integration of the subsequent events of picture 3 and 4. In the simultaneous regimes, pictures 3 and 4 were processed for a longer time, may be because of the added information searching time. Participants in the sequential regime spent more time on picture 2 than on picture 3, while with those in the simultaneous regime this situation was reversed.

There are several limitations to address to the possible impact of the present study.

(i) Results showed significant comprehension differences between the 5 computer graphic messages tested. We used strict scoring criteria, and while a majority of the messages (delay, work on track, platform change) seemed to be very well understood others (strike, yellow line security) had less good comprehension scores. We are currently redesigning and testing new versions of the less efficient messages. This new design of the messages is based on two sources of information: the realization of international comparisons for the comprehension of the messages (Lowe, Boucheix, Groff, Paire-Ficout, in prep.); and the analysis of the wrong comprehension answers recorded in previous experiments.

(ii) The present results come from one experiment designed according to a conventional comprehension paradigm. Are these results robust enough to be a consistent base which could guide the design of more effective and efficient railway disruption messages for the National French Railway Organization? This statement addresses also the question of the generalization of the results to a more ecological railway situation, including time pressure. Firstly, a second experiment was conducted recently, with another group of 75 participants, using exactly the same conditions, the same messages and the same pictures as the present study but in a different spatial arrangement of the pictures. In the present study a linear format, "in row", wad used (figures 1 and 2). In the second study an integrated format ("in column") was used. This second study gave exactly the same result as the first experiment for both comprehension and eye movement measures.

Secondly, in this experiment time on task was not manipulated. A conventional comprehension test was used. We did not start with an online comprehension test of the graphics (with the pictures still present) and/or in a more ecological situation, which could measure how much time it takes to understand the message. And, in practice, do participants process all the pictures? Do they always start at the beginning of the sequence of pictographs? Given the practical goal of such research using animation, a more ecological approach would be very valuable. But this approach characterizes a different, and complementary, side from the goal of the present study. As it was evoked in the method section, the experiment reported in this paper is a core part a broader project involving a larger series of investigations, each having a specific goal. A future study is planned yet, in the broader project, for testing online comprehension of the message (and the subsequent decision, e.g., what to do) using a more ecological environment of railway station (e.g., a virtual station), including time pressure and a largest (more diverse) sample of travelers. The aim of the present experiment was to test more exhaustively the cognitive processes in the comprehension of the messages and their pictures. This was considered a basic stage of a more complete investigation of pictographic messages comprehension which required giving participants enough (but not too much) processing time and implied that participants processed the same "amount" of information. In addition, eye movement's recording is not reliable when participants are speaking while processing the pictures. Silent processing and verbal response have to be separated (Hyönä & al., 2003).

In sum, these results suggest that, in railway public information, visual alternative to traditional spoken announcements, which consist in series of dynamic pictographs, are efficient to convey quickly announcements meaning, "non-verbally". Such dynamic sequential graphic presentation was aligned on the structure of the traveler's internal scripts of the train disruptions, and appeared to map perfectly with them.

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Highlights

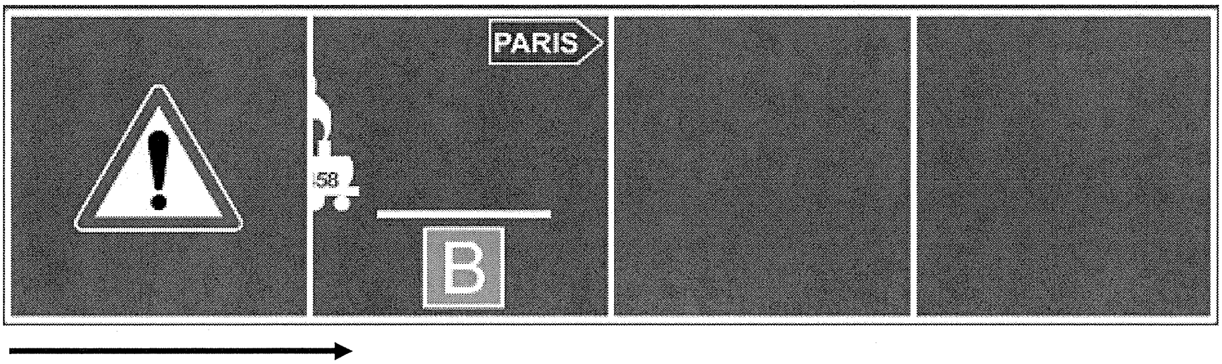
- Computer graphic animation used to deliver public messages instead of announcement
- Animated sequential presentation better understood than static simultaneous format
- Animation promptly trigger in traveler's mind task-appropriate script of events
- Eye movements showing animation enhance efficient task-related strategies
- Animation provide best condition for segmentation-composition of chain of events

Appendix A

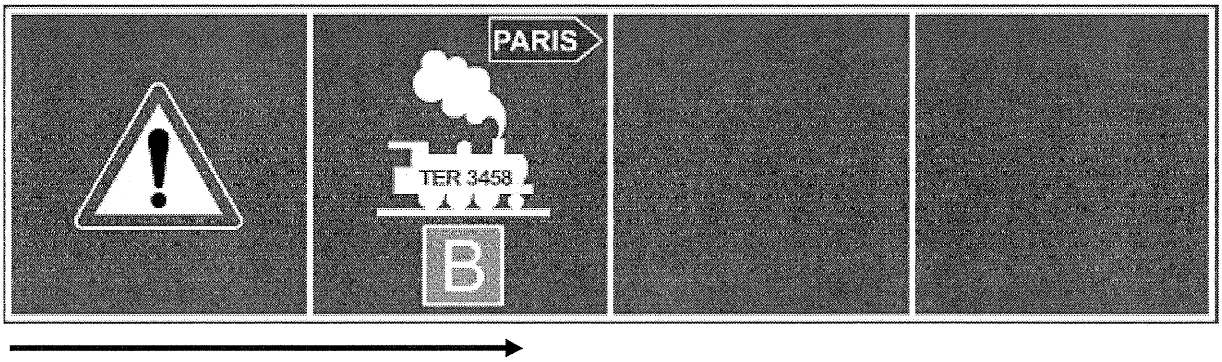
An example of the decomposition of the appearance of (i) each component in the animated sequential condition and of (ii) each whole picture in the static sequential condition.

(i) Animated Sequential condition:

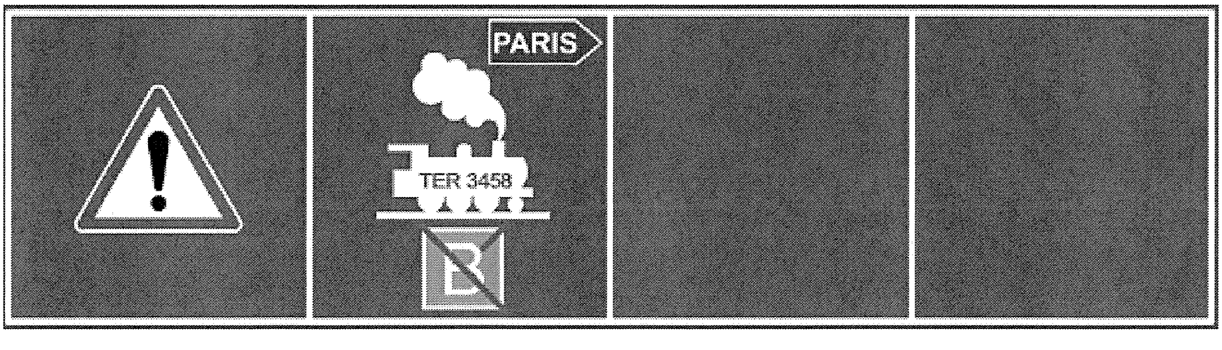
In the example presented in the figures below, for the switching of railway track message; in picture 1, first the warning sign appeared with an intermittent spot light behavior; second, in picture 2, the train (Regional Train, n° 3458) moved from the left side of the picture to the middle of the picture, then the platform B panel appeared and progressively a red cross dynamically overlaid the B label; third, when picture 3 appeared, an animated red arrow moved from the left (B panel) to the right side, then the platform D panel appeared progressively; fourth, in picture 4, a traveler character was shown walking and two animated arrow indicated how to go from platform B to platform D, by going downstairs and upstairs using the underground corridor. In this format, sequentiality across pictures and animation inside of each picture were cumulated.



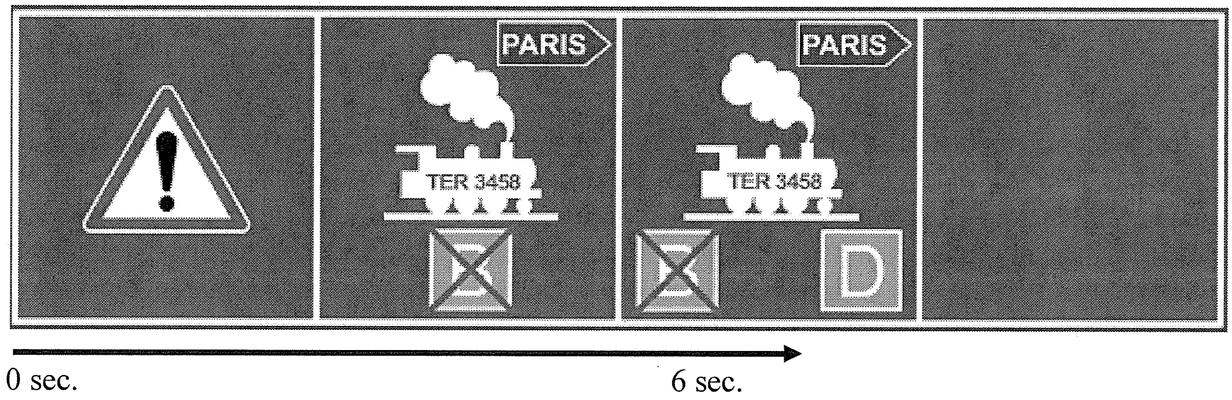
0 sec. 2 sec.

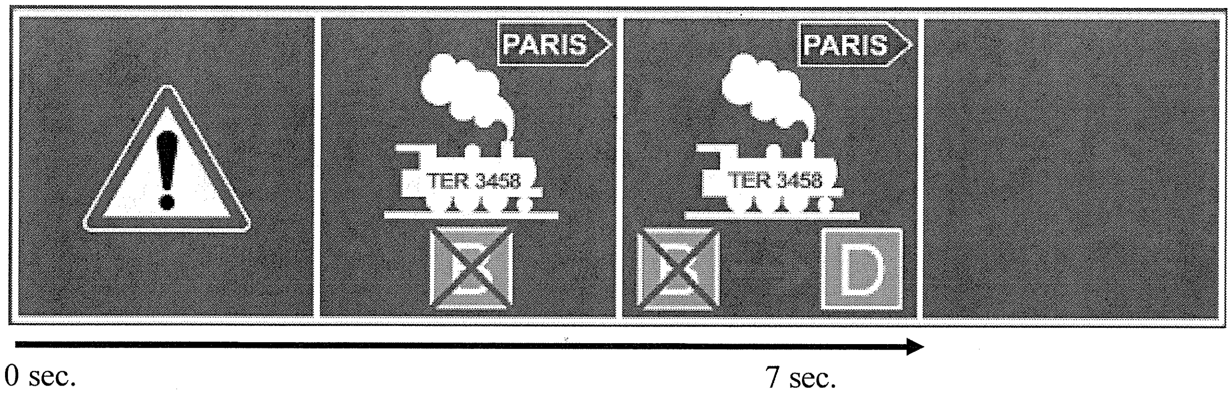


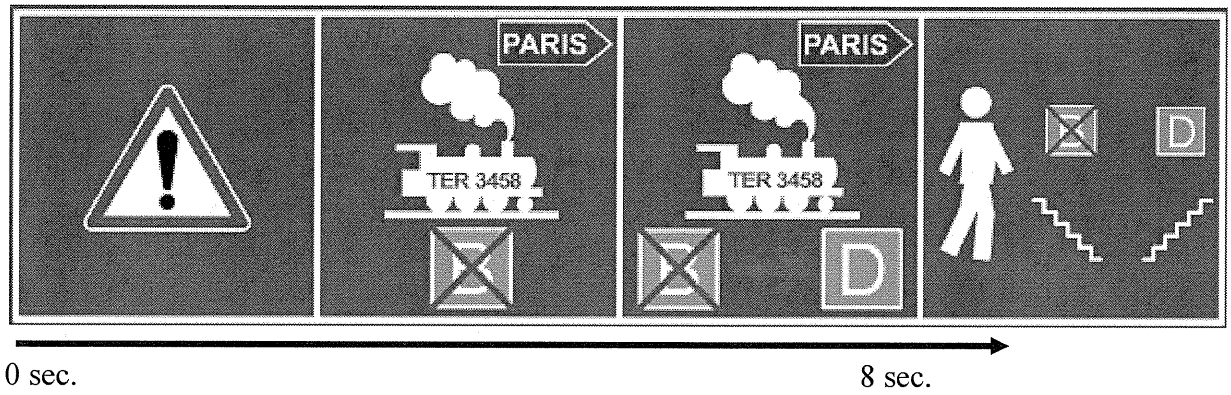
0 sec. 4 sec.

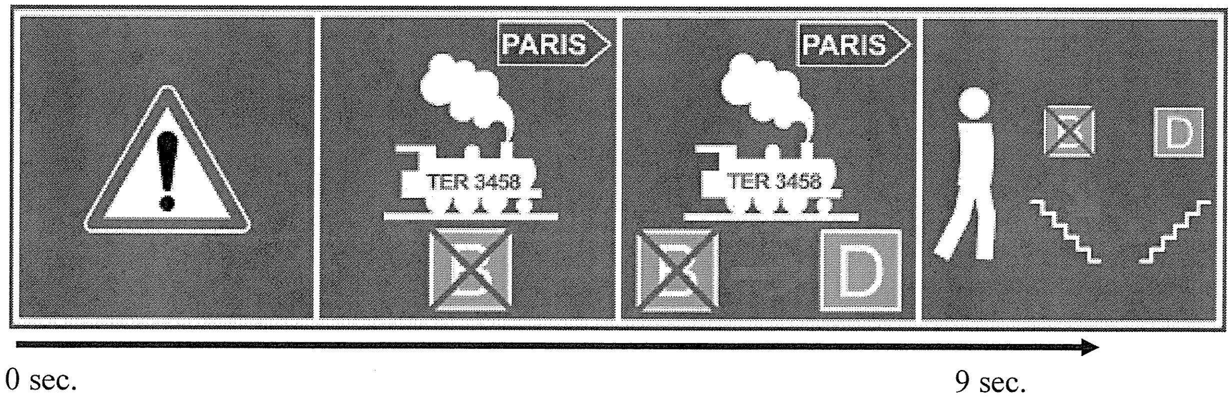


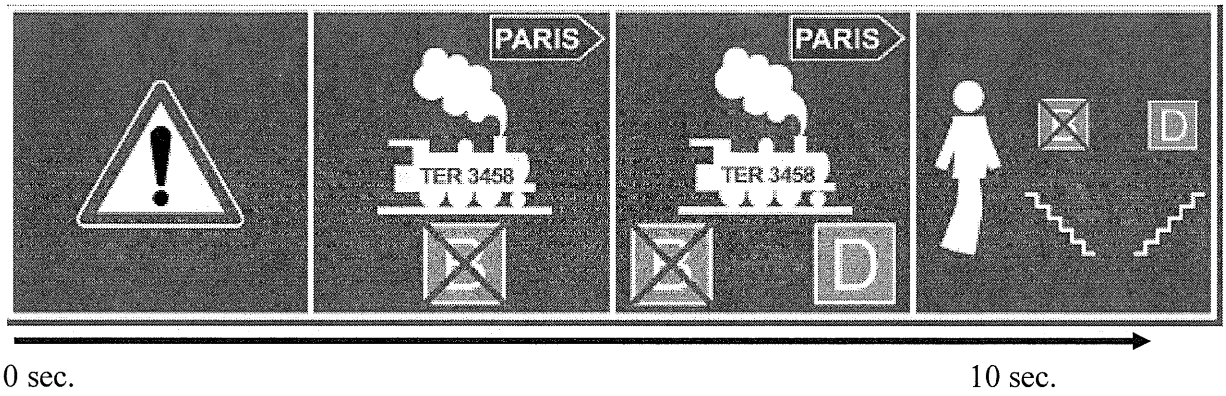
0 sec. 5 sec

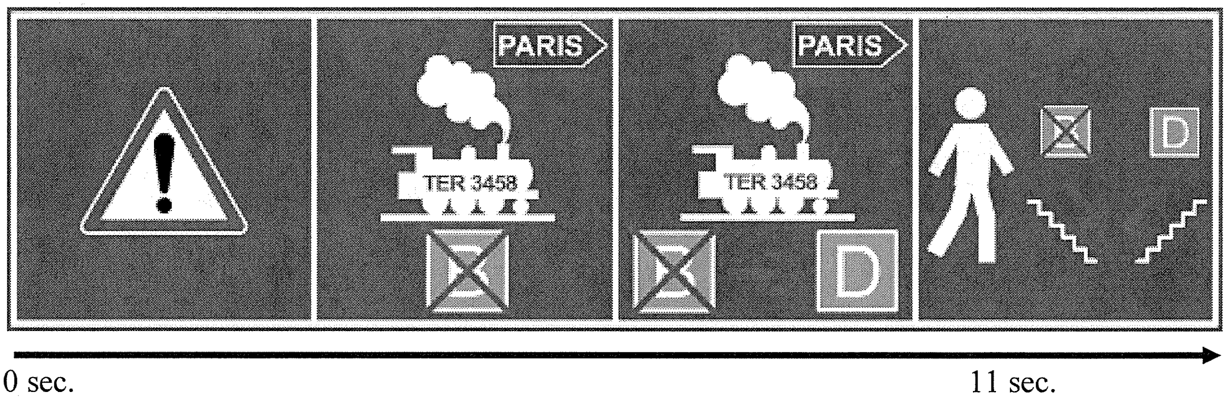

PARIS
TER 3458
PARIS
TER 3458
D
0 sec.
6 sec.


PARIS
TER 3458
PARIS
TER 3458
D
0 sec.
7 sec.


PARIS
TER 3458
PARIS
TER 3458
D
D
0 sec.
8 sec.

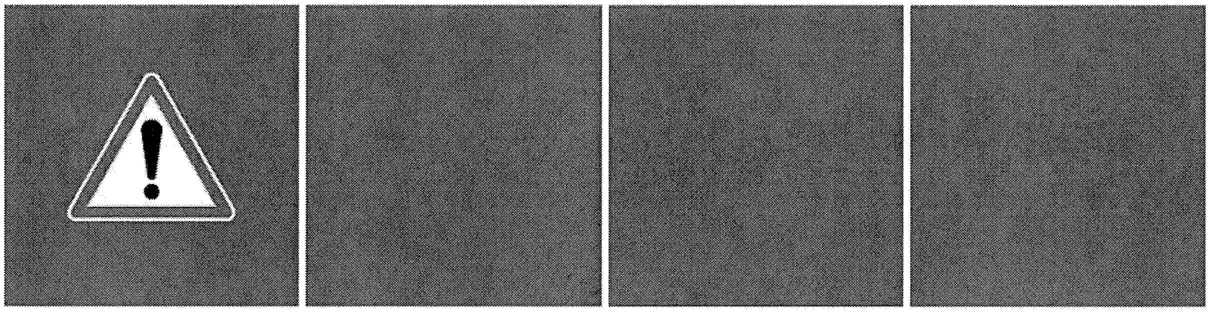

PARIS
TER 3458
PARIS
TER 3458
D
D
0 sec.
9 sec.

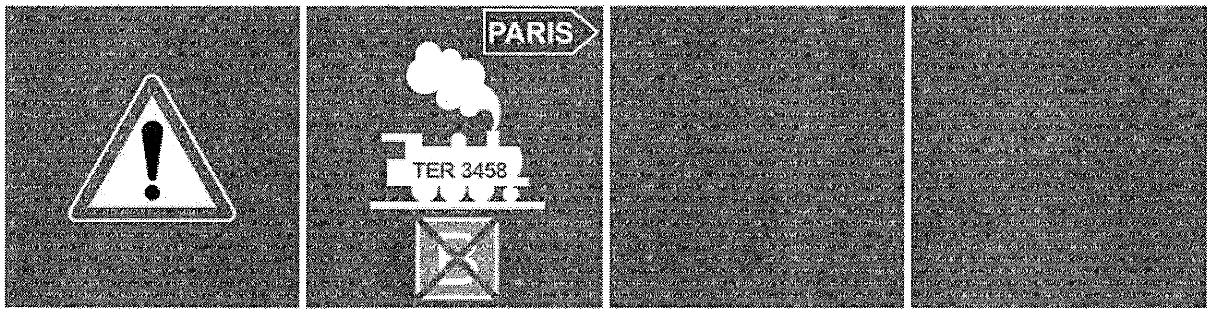


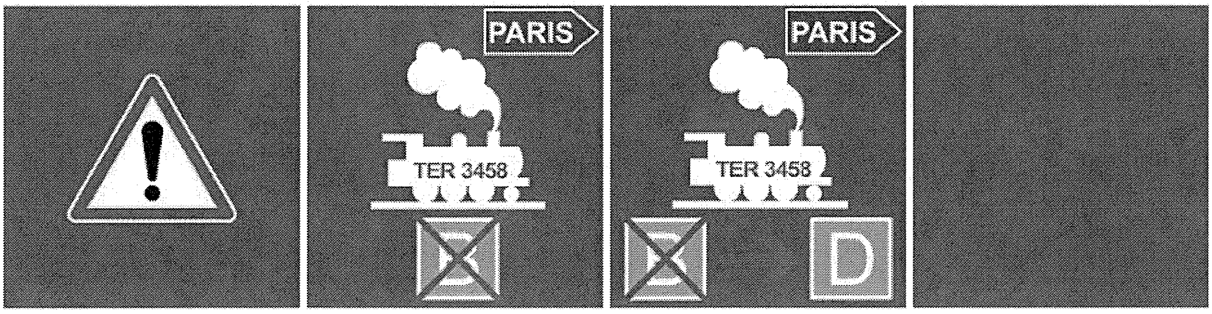


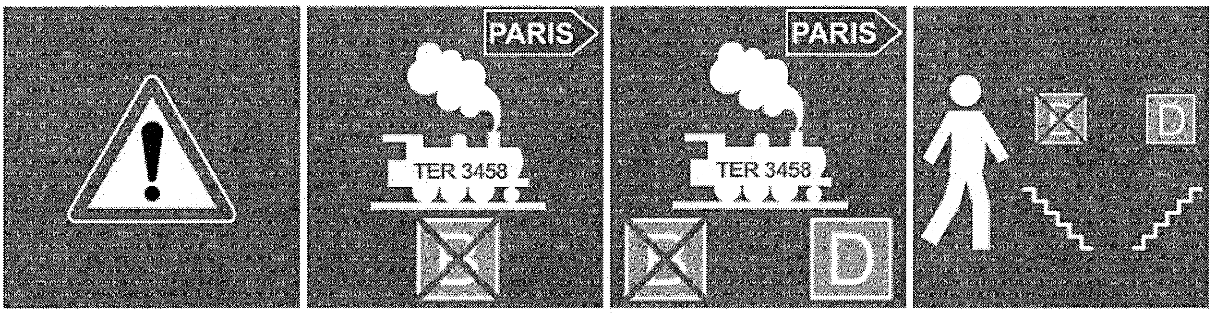
(ii) Static sequential condition

In the example presented in the series of figures presented below, for the switching of railway track message, each whole picture appeared, with static components, one by one. In this format, whole static pictures were presented sequentially. The time progression is the same as in the animated format.






PARIS
TER 3458
B
PARIS
TER 3458
B
D


PARIS
TER 3458
B
PARIS
TER 3458
B
D
B
D

Appendix B

Scoring grid used in the comprehension test for the verbal answers of participants for each visual component of the message. The core event of each message, **in bold in the table below,** was always credited two points.

Message type	Scoring grid	Total
Platform switch	(Your attention please), the Regional Train n°3458: 1; for Paris: 1 **will not start from platform B: 1; but will start from platform D: 1** please take the underground pathway: 1	5
Train cancellation	(Your attention please) because of public work : 1 the train n° 5843: 1; for Paris: 1 **will be cancelled: 2** please go to the information desk: 1	6
Strike	(Your attention please) because of a strike: 1 **several trains :1 ;could be cancelled: 1** **please check**, at the information board: 2	5
Nonstop high speed train pass	(Your attention please) **do not cross the yellow line: 2** **Stay beyond the line: 2** A nonstop high speed train may pass: 1	5
Train delay	(your attention please), because of the weather conditions: 1 the regional train n°4538: 1; for Paris: 1 **will be delayed: 1; by 15 minutes: 1**	5

Tables

Message Type	Animated Sequential	Animated Simultaneous	Static Sequential	Static Simultaneous
Platform switch	59.13 (28.47)	36 (23.03)	55 (24.83)	37.14 (30.02)
Train cancellation	75 (20.87	73.33 (14.71)	71.21 (22.53)	63.49 (23.93)
Strike	26.96 (29.91)	31 (29.36)	32.73 (31.80)	33.33 (32.45)
Nonstop high speed train pass	57.39 (27.83)	38 (32.38)	48.18 (25.94)	37.14 (27.77)
Train delay	79.13 (20.43)	65 (17.01)	70 (22.04)	58.09 (30.27)
Total mean all messages	59.52 (15.49)	48.66 (13.72)	55.42 (16.47)	45.84 (17.18)

Table 1. Mean percentage comprehension scores (and SDs) in the four presentation formats of each message

Picture AOIs		AOI 1 (warning)	AOI 2 (cause)	AOI 3 (event)	AOI 4 (action)
Animated Sequential	**P.T. Counts (n)**	**2.05 (3.08)**	**1.92 (1.55)**	**8.61 (4.34)**	**20.26 (3.85)**
	Duration (sec.)	*1.36 (0.42)*	*3.77 (0.71)*	*3.00 (0.50)*	*1.65 (0.43)*
Animated Simultaneous	**P.T. Counts (n)**	**11.73 (7.46)**	**0.99 (0.81)**	**2.42 (1.12)**	**9.89 (2.41)**
	Duration (sec.)	*0.58 (0.34)*	*3.42 (0.58)*	*4.08 (0.78)*	*2.34 (0.40)*
Static Sequential	**P.T. Counts (n)**	**1.68 (1.06)**	**1.32 (0.92)**	**7.06 (3.80)**	**20.31 (3.52)**
	Duration (sec.)	*1.3 (0.34)*	*3.87 (0.57)*	*2.97 (0.51)*	*1.6 (0.43)*
Static Simultaneous	**P.T. Counts (n)**	**10.47 (7.55)**	**1.79 (2.63)**	**3.06 (2.74)**	**11.37 (3.85)**
	Duration (sec.)	*0.68 (0.26)*	*2.93 (0.59)*	*4.25 (0.72)*	*2.42 (0.42)*

Table 2- Mean pre-target (P.T.) counts in number (with SDs) and mean total viewing duration in seconds (with SDs) in each of the four AOIs for each format of the message presentation

Event AOIs		AOI 1 Cause1	AOI 2 Cause2	AOI 3 Event1	AOI 4 Event2	AOI 5 Event3	AOI 6 Act.1	AOI 7 Act. 2	AOI 8 Act. 3
Animated Sequential	**P.T. Counts (n)**	**5.28** **(3.72)**	**9.48** **(4.80)**	**14.6** **(4.76)**	**15.11** **(4.82)**	**20.55** **(4.25)**	**21.98** **(5.74)**	**23.81** **(5.43)**	**23.11** **(5.52)**
	Duration (sec.)	*1.78* *(0.38)*	*1.85* *(0.50)*	*0.88* *(0.35)*	*1.06* *(0.36)*	*0.57* *(0.23)*	*0.57* *(0.38)*	*0.59* *(0.29)*	*0.51* *(0.25)*
Animated Simultaneous	**P.T. Counts (n)**	**2.03** **(1.77)**	**8.85** **(4.52)**	**6.55** **(2.36)**	**8.31** **(3.90)**	**15.72** **(5.45)**	**17.32** **(2.95)**	**17.9** **(4.01)**	**14.47** **(2.68)**
	Duration (sec.)	*1.51* *(0.36)*	*1.81* *(0.46)*	*1.36* *(0.28)*	*1.5* *(0.45)*	*0.8* *(0.38)*	*0.46* *(0.14)*	*0.63* *(0.26)*	*0.89* *(0.24)*
Static Sequential	**P.T. Counts (n)**	**6.44** **(4.17)**	**9.87** **(4.10)**	**16.8** **(4.41)**	**17.41** **(5.89)**	**19.55** **(4.47)**	**22.8** **(6.37)**	**20.27** **(7.51)**	**21.43** **(5.92)**
	Duration (sec.)	*1.84* *(0.48)*	*1.70* *(0.59)*	*0.75* *(0.46)*	*0.93* *(0.35)*	*0.58* *(0.35)*	*0.47* *(0.33)*	*0.75* *(0.53)*	*0.59* *(0.25)*
Static Simultaneous	**P.T. Counts (n)**	**4.24** **(3.26)**	**12.41** **(5.65)**	**6.36** **(3.23)**	**12.56** **(5.59)**	**14.55** **(5.95)**	**21.16** **(1.07**	**18.69** **(5.47)**	**16.63** **(4.05)**
	Duration (sec.)	*1.28* *(0.40)*	*1.52* *(0.35)*	*1.3* *(0.51)*	*1.37* *(0.47)*	*0.8* *(0.43)*	*0.39* *(0.16)*	*0.53* *(0.24)*	*0.96* *(0.38)*

Table 3- Mean pre-Target counts in number (with SDs) and mean total viewing durations in second (with SDs) in each of the eight AOIs for each format of the message presentation

Figures captions

Figure 1. Example experimental graphic that corresponds to the following announcement text: *"Your attention please (picture 1). Contrary to the information that has been displayed, the Regional Train (TER) number 3458 for Paris will not start from platform B (picture 2) but will start instead from platform D (picture 3). Please take the stairs to access platform D (picture 4)"*.

Figure 2. Graphic messages used in static or animated format and delivered simultaneously or sequentially (the train numbers and the names of destination cities did not change neither across the four conditions nor across participants but could change within the series of five messages seen by a participant)

Figure 3. Four picture AOIs, in the platform switch example

Figure 4. Platform switch example showing the eight component AOIs. The area of each AOI is delimited with square in dotted lines each containing the number of the AOIs.