Orienting Response to Visual Cues as an Indicator of Students’ Attention to Online Instruction

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Motivation for the Study

The rapid development internet-based technology along with the availability of user-friendly video capture and editing tools expanded the use of instructional video modules from fully online courses (e.g. Gosmire, Morrison, & Osdel, 2009), to blended courses (Sloan Consortium, 2007, Twigg, 2003), and to more recent enhanced live active learning strategies such as flipped or inversed classroom (Strayer, 2012; Zappe et al., 2009). The research associated with instructional video modules ranged from production and usage evaluation (Copley, 2007; Griffin, Mitchell, & Thomson, 2009), to specific teaching strategies (e.g. Lawson, Bodle, & McDonough, 2007; Schrader, et al., 2003; Shephard, 2003), or comparative use (e.g. Moreno & Ortegano-Layne, 2008). However, there is a lack of research focusing on how various stimuli included in an instructional video can promote and sustain students’ attention.

Using the principles of cue-summation theory (Severin, 1967) we designed an experiment to study learners’ reaction to two types of cues introduced in video lectures. Cue-summation theory suggests that using redundant information increases the efficacy of the learning process (Brashears, 2004) as compared with the same information presented separately. The application of this theory in the field of human-computer interaction suggests multiple cues presented in both audio and video channels in online lectures improve information processing performance through faster and automatic associative processing (McNab, 2009) which, in turn, increases the amount of time learners can dedicate to understanding the concepts.

For this study we designed a set of video lectures with embedded visual events, or cues (Hahn, 1973). Attention to these visual cues was evaluated by measuring changes in heart rate (Graham & Clifton, 1966). Orienting response to visual events in media have been shown to produce a decrease in heart rate (Reeves et al., 1999), with research showing this being an effective measure of short term attention when watching television programs (Lang, Newhagen, & Reeves, 1996). The main motivation of this study was to analyze the potential impact of two specific cues: instructor’s presence and gestures and respectively graphics (e.g. arrows) designed to capture students’ attention, two visual cues frequently used in the design of asynchronous video lectures.

Instructional materials

Instructional materials used in this study were part of a short professional development introductory course in civil engineering. The master instructional video was recorded using Chroma Key compositing technique (green screen); the video editing allowed superposing the instructor over the PowerPoint slides, with him actively pointing toward important parts of the information shown on the slide, which produced a viewing experience similar to physical classroom participation.

From the master instructional video we selected three short 3 to 3.5 minutes videos sequences to create the experimental treatments: 1) introduction, 2) presentation of a basic concept, and 3) presentation of an applied concept. For all three videos, Power Point slides with voice-over narration were used as control, while the two treatments included the following specific visual cues: instructor presence and gestures or arrows appearing on the
The two specific cues complemented non-specific cuing elements such as the text and graphic on the lecture slides (visual cues) or the instructor’s narration (audio cues), experienced by all participants. The nine resulted short instructional videos were used in the development of the experimental research used in this study.

![Figure 1. Sample screenshots: (a) instructor presence and (b) cuing arrows](image)

**Methods**

**Research Design**

For this study we used a completely randomized design where subjects were assigned to one of the six distinct experimental designs generated by combining nine short instructional videos described in the previous section (Table 1).

<table>
<thead>
<tr>
<th>Treatment 1</th>
<th>Video 1 Introduction</th>
<th>Video 2 Basic Concepts</th>
<th>Video 3 Concept Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>Instructor on</td>
<td>Cuing arrows</td>
<td>Voice-over slides</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>Instructor on</td>
<td>Voice-over slides</td>
<td>Cuing arrows</td>
</tr>
<tr>
<td>Treatment 3</td>
<td>Cuing arrows</td>
<td>Instructor on</td>
<td>Voice-over slides</td>
</tr>
<tr>
<td>Treatment 4</td>
<td>Cuing arrows</td>
<td>Voice-over slides</td>
<td>Instructor on</td>
</tr>
<tr>
<td>Treatment 5</td>
<td>Voice-over slides</td>
<td>Instructor on</td>
<td>Cuing arrows</td>
</tr>
<tr>
<td>Treatment 6</td>
<td>Voice-over slides</td>
<td>Cuing arrows</td>
<td>Instructor on</td>
</tr>
</tbody>
</table>

**Participants**

To avoid any bias associated with participants’ familiarity with the instructor, 69 college students (32 males) form a different campus were recruited using a snowball sampling method. Participants were randomly assigned to one of the six treatments resulting in 10 to 12 participants for each treatment.
Participation was voluntary and a $10 meal ticket was provided as compensation. A screening questionnaire ensured that all participants were free of major motor, auditory or visual impairments and they were not currently undergoing any drug treatment for neurological or psychiatric disorders.

**Research Instrumentation and Procedures**

The experiment was conducted in a dedicated facility. Background noise level was minimal and ambient illumination and temperature was similar for all participants. The information was presented on a 19” CRT screen situated about 36” from the subject’s eyes at about eye level. The participants were seated, in a comfortable position (Figure 2). Philips noise cancelling earphones were used to convey the audio from the video. Participants were able to adjust the volume to a comfortable level.

A Pentium III PC running MediaLab and DirectRT (Empirisoft, 2007) was used to deliver both visual and auditory stimuli to the participants. ECGs were recorded using three 10mm Ag/AgCl electrodes located on both forearms (grounding electrode on left arm) and connected to a BIOPAC MP150WS data acquisition system. AcqKnowledge software (BIOPAC, 2007) running on a G4 Power PC Macintosh (Apple) was used to perform real-time ECG recording (at 10 ms interval).

A training video (short animation sequence) presented at the beginning of the experiment was used to familiarize participants with the technology and the setting, reduce anxiety and help them and the researcher make adjustments to the equipment in order to provide optimum delivery and recording parameters.

For each of the three categories of video modules (introduction, basic concept and concept application) the researchers selected as attention cues those times where the instructor either entered in the viewing area or he actively pointed toward a specific area on the slide. An interval of +/- 200 milliseconds around each selected cue was then considered for analysis. The visual cues were time-synchronized across all the experimental videos. Students were randomly assigned to one of the experimental treatments. At the end of the experiment we also asked participants which video they liked most and least and why. Their evaluations were used to triangulate our experimental findings.

**Data Analysis**

The orienting reflex (OR) was first described by Pavlov (1927) as a motor investigative response to an abrupt external stimulus. Subsequent studies linked the OR to cognition and its role in ensuring “contact with the stimulus” in order to facilitate central processing. Research has determined that OR is elicited by stimuli novelty, as compared to an established reference system. These two are of a dynamic nature, with the reference parameters constantly
adapting in response to external stimulation, thus generating habituation and, in time, subsequent decrease of OR to stimuli that fail to deliver enough novel information.

Furthermore, research by Sokolov (1963) determined that OR is also influenced by the significance of the stimulus, not only by its novelty. That is, we tend to be more attentive to external stimuli that have a known significance to us than to those stimuli that are totally novel to us. These findings highlighted the role of OR for examining attention. Changes in heart rate (HR), and specifically HR deceleration immediately post stimulus administration, has been shown to correlate with the OR as a measure of attention. Van der Molen, Somsen and Jennings (1996) further postulated that observed OR as identified by HR deceleration is increased under voluntary attention and anticipation of an incoming event.

The experimental treatments in the current study use video and audio sequences, which represent a multitude of non-specific stimuli. Considering the non-threatening nature of the study and the commonality of the situation for our subjects (attending a video lecture as a college student) the only specific cuing, elements (from a presentation, not from a knowledge perspective) introduced in the videos were abrupt arm movements by the instructor pointing to a specific area of interest on the slides or the abrupt apparition of colored highlighting arrows. The data analysis for this study was focused on observed changes in HR as a measure of OR around these specific moments, in an attempt to evaluate the value of either type of information presentation on being perceived as novel by the subject, thus generating an OR and promoting increased attention to the lecture.

The data collection process produced a relatively large dataset, with more than two million recorded data points. Because such large datasets are relatively difficult to manipulate with traditional desktop statistical software application, for analysis we used a combination of database software applications (MySQL) and programming languages (SQL, Python, and R).

Data cleaning and validation was performed using SQL and Python programming languages. Using the R programming language for statistical computations, new variables (z-scores, average z-scores, grouping variables) were calculated and added to the dataset. Finally, for each event a graphical representation was generated for visual analysis. Following an initial visual inspection of the generated graphics, for each event include in the analysis, a time interval was defined to capture its effects. These intervals were initially set to 300 milliseconds before and after the event and another set of graphics was generated. A more in-depth analysis of the instructional activity around the cueing points provided the basis for adjusting these intervals in an attempt to capture the entire range of effects. In situations when multiple overlapping effects were observed, additional subsets were defined to ensure a usable regression analysis. Finally, an updated graphical representation was generated and analyzed.

**Results and Discussions**

Researchers theorized that visual cues will have an impact on subjects’ attention as measured by the cardiac frequency. It is expected that sustained attention will be manifested through a longer orienting response following the target visual cues, depending on the type of cue offered (instructor’s gestures or cueing arrow) as compared with the control short videos (voice over slides). Orienting response is defined as the decrease in cardiac frequency following the visual cues.

The remaining of this section will present visual analyses of the average cardiac frequency for major cuing points in the video lecture modules used in this study. Pre and post-cue average cardiac frequency will be analyzed to identify the length of the orienting response and the fastness of the recovery post-cure when the instructor was present on the screen, cueing arrows were showed or a combination of the two.

**Impact of Non-Specific Cuing Elements**

The inherent richness of video-based instructional materials continuously exposes learners to visual (text and graphics) and audio (instructor narration) cuing elements. Therefore the first event to analyze is a video sequence that included a new text section on the slide narrated by the instructor (Figure 3). With all subjects being exposed to the same non-specific cuing elements, this point can be considered a control event for our experiment.
The graphical representation of the mean z-scores of the cardiac frequencies for all three experimental groups clearly shows a similar structure of orienting responses following the non-specific cuing element (see Figure 3 (c)).

Figure 3. Orienting response for non-specific cuing (same for all treatments): new text section on the screen. 
(a) video screenshot before; (b) video screenshot after (c) orienting response (average cardiac frequency)

**Impact of Instructor Presence on Screen**

The second aspect we were interested in was if the presence of the instructor on the screen, when no actual presentation gesture are present, will produce a stronger orienting response (OR) than that produced by the non-specific cues in the video. We selected as the event instructor’s entry in the screen in the first part of the introductory video that had no significant text or graphic showing in the background (Figure 4 a, b). Only one of the three experimental groups were exposed to this event. The graphical representation of the average z-scores of cardiac
frequency, curve (1) in Figure 4c, clearly shows that the presence of the instructor created a stronger oriented response. The steeper regression line associated with the measurements for the treatment group (Figure 4c) strengthens this finding.

Figure 4. Introductory video: the instructor standing as the only target cuing: (a) video screenshot before the event; (b) video screenshot after the event, viewed only by the instructor group; (c) orienting response (average cardiac frequency) for all three experimental groups

The stronger orienting response shown in Figure 4c, indicates that, when the non-specific cues in the video are minimal, the presence of the instructor in the video has the potential to engage students in the instructional process.

Impact of Specific Cues on a Text-Based Narrated Slide
The next sequence of events we analyzed was the inclusion of abrupt arm movement synchronized with cuing arrows on a text-based narrated slide as the control group, followed by slower arm movements across the same text section that was initially marked by the cuing arrow (Figure 5 a, b).

![Coordinate geometry](image)

**Figure 5.** Orienting response with both the instructor and cuing arrows. (a) video screenshot with the instructor; (b) video screenshot with the associating cuing arrow; (c) orienting response (average cardiac frequency)

The graphical representations of the average z-score of the cardiac frequency in Figure 5 c show that instructor’s initial abrupt arm movement produced a stronger short-term orienting response (see area “A” on Figure 5 c), but overall the three regression slopes were similar after this initial event, which shows that the cuing power of the non-specific cues was strong enough to attenuate the impact of specific cues. However, the presence of the instructor and of the cuing arrow produced a longer orienting response than the voice-over slides. That is, as shown in Figure 5 c,
the slope associated with the mean z-score of the cardiac frequency for the voice-over slides group (graph 3) changed toward the end into a positive slope (recovery), while the other two regression lines continued on a negative slope (longer OR).

**Comparative Impact of Instructor Gesturing and Dynamic Cuing Arrows**

The final event analyzed in this paper is similar to the previous one, but differs in that the non-specific cuing elements are stronger (diagrams as opposed to text) and the cuing arrows are switching positions following instructor’s major gestures (Figure 6).
Figure 6. Orienting response with both the instructor and dynamic cuing arrows. (a) the instructor before; (b) the instructor after; (c) cuing arrows before; (d) cuing arrows after (e) orienting response (average cardiac frequency)
The graphic representations of the mean z-scores of the cardiac frequency in Figure 5 e indicate that previous to the cueing arrow changes in position the orienting response and the associated recovery followed a similar pattern (see area “A” in Figure 5 e). However, the dynamic change of the cuing arrows produced a significant additional orienting response (see area “B” in Figure 5 e) that was not present when the specific cue was the continuous gesturing of instructor’s arm.

Conclusion

A visual analysis of the average cardiac frequency (mean z-scores) for each treatment, pre and post cue, showed that, for the majority of the studied cues, the longest orienting response was generated by those videos where the instructor was present on screen, followed by the presence of cueing arrows. Voice over only videos showed, in general, the shortest duration of the observed orienting response and the fastest recovery post-cue. However, the presence of dynamic text chunks or of diagrams on the background slides can also produce strong orienting responses in a simple voice-over narration.

Therefore, the visual analysis indicate that, based on the observed orienting response, the presence of either the instructor or the targeted cuing arrow in an online instructional video has the potential to increase attention to the presented material. This was also confirmed by the participants’ subjective evaluation of the videos. Most participants preferred the short video in which the instructor was present, followed by the short videos with cuing arrows. Future work will focus on grounding these findings in statistical analyses appropriated for the nature of the measurements and the richness of the existing dataset.

References


