Studies in the Efficacy of Motion Graphics: How the Presentation of Complex Animation Implicates Exposition

Spencer Barnes

University of North Carolina at Chapel Hill

Abstract

Motion graphics (MGs) are employed in various contexts in order to entertain and inform audiences, and the functionality of an MG is predicated upon the quality of its animation. The research presented in this paper examines the effects that complex animation has on the MG viewing experience by observing how individuals interact with MGs and process the exposition offered by the graphics. A 3 X 3 mixed design study using 96 participants was conducted to further this inquiry and its findings indicated that complex animation is capable of enhancing the efficacy of an MG’s exposition and that the optimization of the MG viewing experience is contingent upon how complex animation is incorporated into MGs.

Motion graphics (MGs) express visual narratives of experiences and convey explanations of phenomena in a variety of contexts. Throughout this paper the terms MG(s) and graphic(s) are used interchangeably and refer to motion graphics. Some graphics are presented in the form of brief advertisement spots for television whereas other MGs accompany online news packages in order to add depth to a feature story (Krasner, 2013; Rall, 2013). The former scenario refers to entertainment MGs and the latter refers to expository MGs, which are the primary interest of this paper. An entertainment graphic serves the purpose of presenting viewers with narratives that “can not only provide enjoyment and emotional experiences, but can also affect individuals’
real-world attitudes and beliefs” (Carpenter & Green, 2012, p. 169). The discourse associated with this type of MG is communicated through graphic storytelling and animation which enables the graphic to engage an audience and offer an entertainment experience to them (Eisner, 2008). People commonly encounter entertainment graphics in the form of film title sequences that foreshadow the general narrative of a movie (Bednarek, 2014). Solana and Boneu (2007) showcase numerous examples of opening and ending credit sequences from popular movies and critically analyze the visual culture surrounding graphics displayed in cinematic contexts.

The function of expository MGs is to visually explain topics, processes, or events to an audience through the use of animation (Ploetzner & Lowe, 2012). Within an expository graphic the phenomenon of interest is usually represented as the feature object and animation enables its behavior to be replicated and simulated. For example, the online news package produced by The New York Times entitled Snowfall: The Avalanche at Tunnel Creek (Snowfall) contains a graphic that demonstrates how snow and ice accumulate on sloped landmasses, eventually loosens, and initiates an avalanche (Franchi, 2013). The snow (represented by white particles) and the layers of ice (represented by white pieces of geometry) are animated pieces of 3D computer-generated imagery (CGI). Typography and graphic elements are used to annotate the action being depicted by the MG. Two static cameras are used: one camera for the shot of layers of snow and ice while the other camera provides a close-up of the frost that acts as a catalyst for the avalanche. The clarity of the graphic’s exposition could be attributed to the minimal amount of animation that was employed but that conclusion would not be definitive because it is unknown whether more complex animation could have further
enhanced the graphic’s efficacy. It is possible that using one or more dynamic cameras that dollied around or through a mountainous landscape could have further contextualized the MG’s subject matter and that more ambient snow flurries could have better informed viewers about the rate of snowfall that predicates an avalanche.

Two previous studies by the author (forthcoming) sought to determine what influence complex animation had on the viewing experience associated with expository graphics. The first study explored whether complex animation made any impact on the viewing experience and if it was advisable to present MGs in prescribed sequences. The second study explored the role of choice in the MG viewing experience and how viewers learned from the graphics that they had chosen to watch. Although both studies advanced the author’s inquiry into the MG viewing experience an overall comparison between all of the conditions presented in each study has not yet been attempted. The purpose of this paper is to expand upon the author’s prior research by examining how complex animation affects the efficacy of expository MGs in situations where viewers are able to decide what kinds of MGs they would like to view and in situations where they do not have a choice. A comparison of those situations should offer some insight about the use of complex animation in the context of expository MGs and the MG viewing experience since very little research exists in the area. Next, the author discusses graphics in further detail and then introduces a framework that describes how individuals interact with graphics during the viewing experience.

**Motion Graphics**

An MG is a hybrid temporal composition that consists of plates (or image layers) housing typography, graphic elements, image sequences, CGI, and live action footage
Adobe Photoshop and Autodesk Maya are software programs that facilitate the creation of those assets and visual effects applications such as Adobe After Effects and The Foundry’s Nuke provide a multifaceted environment where the assets can be placed on plates and the plates can be animated, finished (i.e., color graded), and consolidated into the final composition that constitutes the MG (Lanier, 2010; Skjulstad, 2007; Wood, 2014). Throughout this process animation adds value to the MG and the viewing experience associated with it (Manovich, 2006).

Animation enables the motion of the elements within plates, the plates themselves, and any cameras used. Technically, animation functions as a mechanism that “generate[s] illusory movement by producing and displaying an artificial arrangement of graphic positions without reproducing the positions of real-time movement” (Martinez, 2015, p. 42). Most visual effects applications permit users to specify how animation occurs through the use of key frames which allows the user to set the initial and end state of an object, camera, or plate while letting the application interpolate or produce motion and change between the two states (Jones, 2007; Krasner, 2013).

Viewers of an MG benefit from animation because of its capability to “portray temporal change directly and explicitly” (Lowe & Schnotz, 2014, p. 513) by representing the spatial and temporal configuration of objects or events over time, which allows a person to observe the development and progression of action. People are able to achieve an understanding of a graphic by producing a mental model of the action that it contains. A mental model is one’s conceptualization of an object, event, behavior, or phenomenon and it is formed as a result of viewing animation (Johnson-Laird, 1980, 1996, 2005; O’Malley & Draper, 1992). The creation of a mental model involves multiple steps and
begins with a person attempting to mentally parse the animation(s) that they have just viewed. They decompose it based on the hero item(s)\(^1\), ambient objects, and background environment being displayed by the MG. The viewer attributes meaning to these separate components of the animation and then integrates them into separate causal chains. The causal chains are then assembled into an internal analogical narrative that describes what the MG’s animation depicted and this forms the substance of the person’s mental model (Lowe & Schnotz, 2008, 2014; Torre, 2014). This narrative serves as the basis for the mental model and it allows a person to derive inferences, engage in inductive reasoning, and retrieve and apply knowledge during task performance. Since the accuracy and efficiency of a mental model is determined by the quality of information that an individual consumes, it is reasonable to expect that a person’s mental model can also be affected by the type of animation to which they are exposed.

Varying levels of animation can be integrated into a graphic depending on the nature of the graphic’s subject matter or the intent of the designer. Within some MGs only the hero items are animated, all of the other assets and cameras remain static, and there is only one shot presented to the viewer. In other MGs animation is applied to the hero and ambient objects, there is synchronous motion between the plates and their assets, and several dynamic cameras are used to present different shots to the viewer. The latter scenario encompasses complex animation and it would seem that complex animation is capable of making the viewing experience more engaging and providing viewers with more information but researchers have expressed ambivalence about its

\(^1\) A hero item (actor or object) is the featured component of an MG and the action being depicted. It is central to the visual explanation being conveyed and the development of an audience’s understanding of the graphic.
advantages and disadvantages. Complex animation could draw a viewer’s attention to relevant concurrent and sequential action within an MG which could lead to the production of a robust mental model that allows a viewer to engage in efficient mental animation as they reason through tasks (Hegarty, Kriz, & Cate, 2003; Kriz & Hegarty, 2007). However, complex animation could cause a viewer to develop an incomplete or erroneous mental model because they are focused on irrelevant action and information. Because the incorporation of complex animation into an MG could be just as detrimental as it could be beneficial it becomes necessary to achieve a better understanding of the MG viewing experience and the next section introduces a framework to do so.

**Characterizing the MG Viewing Experience**

The MG viewing experience begins with a person’s initial exposure to an MG in its native venue. Native venues for graphics include online news packages, websites, mobile applications, or television spots and within any of these settings people may or may not have control over what graphics they view (Franchi, 2013). For instance, most of the graphics housed in Snowfall are integrated into the online news package and automatically play as soon as a viewer gets them within their screen’s display range. As the viewing experience proceeds the person watches the MG, makes efforts to comprehend its content and animation, and forms a mental model from the information that they have ascertained. Lastly, the person applies their acquired knowledge towards a goal (e.g., task performance). The preceding account illustrates the procedural aspects of the MG viewing experience but it does not explain how the viewing experience can be optimized. However, the theory of naïve realism and cognitive load theory address this matter from complimentary perspectives.
Naïve Realism

The theory of naïve realism originated from cognitive psychology research on visual displays and it focuses on people’s interaction with visual media stimuli (VMS) such as MGs prior to, during, and after task performance. The theory suggests that individuals have expectancies about the viewing experience associated with the VMS to which they are exposed, that these expectancies are influenced by certain characteristics of the VMS, and that task performance is indirectly impacted as a result (Smallman & St. John, 2005a). People erroneously assume that the appearance and design of VMS actually reflects how well it affords task performance and they tend to hold a counterintuitive belief that more detail makes VMS more effective. They fail to realize that there is a threshold at which performance deteriorates due to excessive detail (Smallman & St. John, 2005b). In the case of graphics excessive detail comes in the forms of photorealistically rendered objects, depth cues, complex animation, or any other superfluous aspect of an MG that misdirects viewers’ attention. Excessive detail is immersive and produces visual clutter that causes distraction, misdirection, and makes it difficult for viewers to recognize and isolate objects and action that are relevant to understanding an MG’s content (Bracken, 2005; Rooney & Hennessy, 2013; Rosenholtz, Li, & Nakano, 2007; Tran, 2012). Therefore, the theory asserts that the utilization of VMS containing excessive detail will lead to a substantial decrement in the accuracy and response time associated with task performance whereas the usage of VMS with a low amount of detail will lead to superior performance (Hegarty, Canham, & Fabrikant, 2010). Naïve realism is exhibited as a behavior when a person prefers to use VMS with
excessive detail as a basis to complete comprehension and problem-solving tasks when VMS without excessive detail will suffice and provide better task performance.

**Variables associated with the theory of naïve realism.** Three variables are used to evaluate naïve realism as a behavior: presentation quality preferences, intuition, and accuracy. Presentation quality represents the amount of excessive detail that VMS possess; if a graphic has more detail (i.e., excessive detail) it is considered to have a higher amount of presentation quality than a graphic that has less detail. In this paper presentation quality will also be referred to as *fidelity*. The constituent features of presentation quality are animation, realism, complexity, and 3D. Animation pertains to the quality of the temporal motion incorporated into VMS in order to simulate action, realism concerns the degree of iconicity or visual similarity (i.e., representativeness) that VMS have to their depicted phenomena, complexity describes the amount of visual clutter included in VMS, and 3D refers to the dimensionality possessed by the VMS. The presentation quality preference scale developed by Hegarty, Smallman, Stull, and Canham (2009) is used to assess how desirable as well as how effective people find those features to be during the MG viewing experience. Throughout the course of several studies the scale was found to have a reliability coefficient ($\alpha$) of 0.72 which means that it consistently produces exact measurements of presentation quality preferences. An $\alpha$ less than 0.7 indicates that a scale lacks precision and produces inconsistent measurements (Field, 2009).

An intuition is a viewer’s expectancy about VMS and a prospective intuition is an expectancy recorded prior to exposure to VMS and a retrospective intuition is an expectancy recorded after exposure. Prospective intuitions are based on viewers’
assumptions and expectations about the task demands and relative utility of the different display formats, while retrospective intuitions reflect participants’ experiences with the task” and VMS (Smallman & Cook, 2011, pp. 597-598). Prospective intuitions indicate one’s preference for specific VMS and their prediction about its effectiveness, and retrospective intuitions measure how effective VMS was during task performance according to the viewer. Prospective intuitions serve as a baseline for retrospective intuitions and their comparison permits one to observe whether naïve realism is being exhibited. Intuition rating trials record intuition by presenting alternative yet compatible VMS to viewers and requiring them to predict which VMS will best support task performance.

Accuracy relates to how well viewers comprehend information from VMS and apply this knowledge during task performance. Accuracy is measured in the form of viewers’ correct responses to a series of comprehension questions pertaining to recently seen VMS. Additional insight about the exhibition of naïve realism can be gained by combining assessments of the amount of comprehension achieved from VMS with the measurement of intuition (Hegarty, Smallman, & Stull, 2012).

Cognitive Load Theory

This theory covers the acquisition and processing of information originating from the exposition offered by VMS (Sweller, 1988; 2010). For the purpose of this paper, exposition will be defined as any instruction, information, or knowledge implicitly or explicitly conveyed by VMS that results in comprehension and learning. Human cognitive architecture consists of sensory memory, working memory, and long-term
memory, and according to cognitive load theory these components operate in unison to process information and achieve comprehension (Gredler, 2005; Strayer & Drews, 2007; Kalyuga, 2009, 2010). Learning occurs when new information elaborates and alters knowledge held in long-term memory, and the application of learning can be observed when the information is retrieved during task performance (Paas & Sweller, 2014).

Working memory is the most critical component of human cognitive architecture during information processing for three reasons: 1) it acts as an intermediary between the initial acquisition (sensory memory) and ultimate storage of information (long-term memory), 2) it is where the majority of information processing activities take place (i.e., encoding and retrieval), and 3) it is resource-based (Wickens & Holland, 2000). Working memory is limited to maintaining between five to nine pieces of novel information at any given time and once its capacity is exceeded one experiences cognitive load (CL; Baddeley, 2012; Miller, 1956). It takes mental effort to hold information in working memory no matter if the information is being encoded and is headed toward long-term memory, or if the information has just been retrieved from long-term memory. More mental effort gets exerted as the capacity of working memory reaches exhaustion, which produces more CL (Moreno, 2010; Moreno & Park, 2010). Behaviorally, CL is indicated by the difficulty that one has learning new information and by the difficulty that they have completing tasks that require an understanding of that information (Schnotz & Kürschner, 2007).

**Variables associated with cognitive load theory.** The most succinct and unobtrusive way to measure CL is offered by Paas’ (1992; Paas & van Merriëboer, 1993) 9-point CL scale. The underlying premise of the instrument is that people are capable of indicating the amount of CL that they are experiencing (Paas, Tuovinen, Tabbers, & van
Gerven, 2003). The 9-point CL scale is symmetrical with the response of “neither low nor high mental effort” lying at its center and poles labeled “very, very low mental effort” and “very, very high mental effort”, respectively (see van Gog & Paas, 2008 for a review of studies using the scale). The 9-point CL scale has an $\alpha$ of .90 which means that it is capable of providing very precise and consistent measurements of CL. It can be administered during learning or task performance (i.e., online) or immediately following those activities (i.e., offline), and the 9-point CL scale is capable of producing comparable measurements of CL within and between various learning situations and tasks. van Gog, Kirschner, Kester, and Paas (2012) cautioned researchers that participants have a tendency to overestimate as well as underestimate the amount of CL imposed by learning or task execution when they are only required to provide a CL measurement after the completion of a series of activities. The researchers therefore recommended that iteratively taking CL measurements throughout learning and task performance and subsequently averaging them would be one way to assure that the CL data would be unbiased and avoid inflation. In the case of MGs it is advisable to have CL measured immediately after the completion of any comprehension task (e.g., after responding to each question).

**Framework and Previous Research**

The aforementioned theories establish a framework that makes a more robust reconsideration of the MG viewing experience possible. The theory of naïve realism addresses the interaction(s) individuals have with a graphic during the viewing experience and cognitive load theory demonstrates how individuals engage in information processing once they begin interacting with the graphic. A person’s
interaction with an MG begins with their initial exposure to the graphic which may occur under two circumstances: either the individual chooses to view a particular graphic or they are required to view a specific graphic due to the venue in which the graphic is housed. Next, the person views the graphic. These first two steps of the MG viewing process are external to the viewer and the theory of naïve realism covers the viewer’s response to the MG as dictated by their expectancies of the graphic. The remaining steps of the viewing experience are internal to the viewer and pertain to cognitive load theory and how human cognitive architecture is employed for the purpose of comprehension. While watching the MG the viewer processes the information that they have acquired from the MG’s content and animation and forms a mental model. Finally, the mental model is applied toward to a task.

The rationale of the framework is informed by the confluence of the theory of naïve realism and cognitive load theory because both theories suggest that including large amounts of excessive detail in an MG (e.g., complex animation) is counterproductive for task performance. The visual clutter produced by excessive detail is often times the most salient aspect of a graphic which makes it alluring to viewers but visual clutter is usually irrelevant to the actual exposition of the graphic (this is within purview of the theory of naïve realism). When a viewer becomes engaged with visual clutter their cognitive architecture is directed towards processing irrelevant information. This exhausts the person’s working memory capacity, which imposes cognitive load and leads to the formation of either an incomplete or flawed mental model because irrelevant information was used as a knowledge source (this is within the purview of cognitive load theory). The utilization of this mental model results in inaccurate and latent task performance. Each
theory recommends that a reduction in excessive detail will result in the optimization of the MG viewing experience.

Earlier research conducted by the author used this framework to analyze the effects produced by expository MGs containing complex animation. In the first study 82 participants were randomly assigned to two groups and viewed predetermined sequences of MGs. One group viewed a graphic with complex animation and then viewed a graphic without complex animation, and the other group viewed the graphics in reverse order. Participants’ intuitions, comprehension, and CL were recorded throughout the study. The results indicated that the participants’ initial intuitions were driven by their presentation quality preferences but during and after exposure to the respective MG sequences the participants’ intuitions were informed by the most recent MG that they had viewed. Also, the participants demonstrated better comprehension of the content originating from the graphics without complex animation. The second study introduced choice into the viewing experience by allowing 135 participants to choose what type of graphics they wanted to view. Specifically, on two occasions during the study the participants were able to choose between an MG with complex animation and MG without it (on each occasion both versions of the MG depicted the same topic). The outcomes of this study countered the results of the first study because the participants overwhelmingly chose to view graphics with complex animation and the use of those types of graphics did not adversely affect the participants’ comprehension. The results suggested that consistent or continual exposure to complex animation enhances information processing and enables one to refine and adapt their mental model. These findings are somewhat contradictory as well as limited because the MG viewing scenarios presented in each study have not been
directly compared to each other. The current study seeks to address this issue by comparing the efficacy of the aforementioned MG viewing scenarios within one experiment and the following research questions advance this inquiry:

**RQ1:** Which viewing scenario(s) exacerbated naïve realism and which viewing scenario(s) mitigated it?

**RQ2:** Which viewing scenario(s) was the most conducive for comprehension?

**RQ3:** How does the presentation of complex animation implicate exposition during the MG viewing experience and what is the optimal viewing scenario in which to incorporate complex animation?

### Method

**Participants**

The sample was composed of 96 undergraduate students (62.1% female) enrolled in a public university within the US. Their mean age was 20.69 years ($SD = 1.40$). Prior to the beginning of the study the participants were required to complete a preliminary demographic survey that documented their news consumption habits and presentation quality preferences. The participants reported that approximately they viewed online news for one hour and 18 minutes per day, viewed television news for 39 minutes per day, and read newspapers for 17 minutes per day. Also, only 67.7% of the participants indicated that they viewed MGs with some degree of frequency, 31.2% indicated that they viewed MGs infrequently, and 1% of the participants reported not viewing MGs at all. Entertainment websites served as main venue where the participants viewed graphics (77.1%) and news websites constituted another venue (19.8%). The participants’ remaining sources for graphics were educational websites and content repositories like
Behance (3.1%).

**Materials**

**Stimuli.** Four expository MGs that were 1280 by 720 pixels in size were used. Each graphic had duration of 45 seconds. The animated CGI for the graphics was generated using Autodesk Maya, the graphic elements and animated typography using Adobe Illustrator, and all of the items were composited and output to digital movie files by Adobe After Effects. Audio narration supplemented the visual explanations offered by each of the MGs. Two of the graphics were high fidelity meaning that they contained multiple shots using several virtual cameras and realistic rendering, and two of the graphics were low fidelity meaning that they only contained one shot using a stationary camera and two dimensional toon shading. The occurrence of a Middle Eastern dust storm was depicted in a high fidelity graphic as well as a low fidelity graphic and so was the behavior of blue marlin (see Figure 1).

*Figure 1. Frames from the expository graphics, low fidelity MGs (top row) and high fidelity MGs (bottom row).*
**Apparatus.** The study was conducted in a computer lab equipped with 27-inch Apple iMac desktop computers.

**Instruments.** The preliminary demographic survey, which was referred to earlier, required participants to provide information about their age, news consumption habits, and where they routinely viewed MGs. It also recorded the participants’ presentation quality preferences because an adapted version of the presentation quality preference scale ($\alpha = .72$) developed by Hegarty, Smallman, Stull, and Canham (2009) was incorporated into the survey. Animation was not assessed as a presentation quality preference since the current study focused on manipulating the presence of complex animation within expository graphics. The questionnaire’s six items asked participants to rate how desirable and effective they would find the attributes of realism, complexity, and 3D to be during their MG viewing experience (-2-very ineffective/ very undesirable to 2-very effective/ very desirable). For all six items values less than “0” indicated the degree of undesirability or ineffectiveness, respectively, and values greater than “0” indicated the degree of desirability or effectiveness, respectively.

Each expository MG was followed by three multiple-choice questions and each question featured four response options which were designed to assess the participants’ learning or task performance. The 9-point CL scale documented the amount of CL that the participants experienced at various times during the study (-4-very, very low mental effort to 4-very, very high mental effort). Values less than “0” indicated that people experienced low amounts of CL and values greater than “0” indicated that people had experienced high amounts of CL. A value of “0” indicated that no CL had been experienced during task performance.
Intuition rating trials were administered to participants three times during the study to document their general expectancies about MGs. Each intuition rating trial contained two static images depicting the same subject matter: one image was high fidelity and the other image was low fidelity. The CGI for the static images was generated using Autodesk Maya and the images were output via Adobe Photoshop. Each pair of images was comparable and their subject matter pertained to fan coral, hyacinths, and Mesoamerican pyramids. Each intuition rating trial required participants to choose what image they thought would be the most helpful in answering questions about the subject matter and then predict how helpful their choice would be using a symmetrical five point scale (-2-very unhelpful to 2-very helpful). Values less than “0” represented the degree of predicted unhelpfulness of the choice and values greater than “0” represented the degree of predicted helpfulness of the choice.

MG selection trials were similar to the intuition rating trials but they were only fully administered to participants within the choice condition of the study since all of the other participants had to view predetermined sequences of MGs. MG selection trials were comprised of two parts. The first part recorded what type of expository graphic each participant chose to watch at each opportunity to view a graphic. The second part was filled out after the participant actually viewed their chosen graphic and asked the person to indicate how helpful they actually found the graphic to be (-2-very unhelpful to 2-very helpful). Participants in the other conditions also reported how helpful each expository graphic they viewed had been although they were not required to complete full MG selection trials.

Design and Measures
This study utilized a 3 X 3 mixed design with a between-subjects factor of condition and a within-subjects factor of exposure. Condition had three levels (i.e., HL, LH, and choice) which represented the different sequences of expository MGs that the participants were randomly assigned to view. The choice condition housed 33 participants, the HL condition housed 27 participants, and the LH condition housed 36 participants. Participants assigned to the HL condition viewed a high fidelity graphic then a low fidelity graphic and participants assigned to the LH condition viewed a low fidelity graphic and then a high fidelity graphic. Participants in the choice condition were able to choose whether the first expository MG that they viewed was a high fidelity graphic or a low fidelity graphic, and if the second expository MG was a high fidelity graphic or low fidelity graphic. Exposure consisted of the three time points when all of the participants had their intuitions recorded (see Figure 2). The dependent variables are categorized by the operational construct that they represent and Table 1 displays all of the dependent variables and their associated instruments.

**Figure 2.** Diagram of the study’s procedure. Each intuition rating trial is represented by IRT.

**Intuition trend.** The general pattern of intuitions exhibited by the participants, was a between-subjects factor and it served as a clustering variable for facilitating data
Participants that chose a high fidelity image on their final intuition rating trial were considered to be naïve whereas individuals that chose a low fidelity image were considered not to be naïve (non-naïve). Meyers, Gamst, and Guarino (2013) demonstrated the rigor and applicability of clustering or grouping participants based on information acquired during the course of a study and then using the groupings during data analysis. The use of the participants’ final intuition rating trial choice as a means of clustering is consistent with the research of Smallman and Cook (2011, p. 597) because the groupings reflect observed patterns of intuitions and allow the researcher to establish the participants’ intuition trend(s).

Variables related to intuition. Presentation quality preferences, intuition, intuition helpfulness, initial recurrence rate, and secondary recurrence rate were the dependent variables pertaining to the operational construct of general intuition.

Presentation quality preferences consisted of the participants’ ratings of the desirability and predicted efficacy of the three presentation quality attributes associated with MGs: realism, complexity, and 3D. Intuition represented the participants’ choices on each intuition rating trial and intuition helpfulness reflected how helpful the participants thought that their image choice would be. As intuition was measured on three occasions, the recurrence of participants’ intuitions over two or more consecutive occasions was calculated as a recurrence rate. The initial recurrence rate corresponded to participants making the same choice on the first and second intuition rating trials, and the secondary recurrence rate corresponded to participants making the same choice on the second and third initial rating trial. Response times (in seconds) were recorded after each intuition rating trial, which resulted in the variable of intuition time.
**Variables related to exposition.** This operational construct addressed how the participants learned from expository graphics and its dependent variables were MG choice, actual helpfulness, accuracy, accuracy CL, and accuracy time. *MG choice* only pertained to participants in the choice condition and it indicated what type of graphic they had chosen to watch at each of the two opportunities to view an expository graphic. The remaining variables pertained to all of the study’s participants and the expository MGs that they viewed. *Actual helpfulness* documented how helpful each expository MG actually was to the participants as they answered its comprehension questions.

Accuracy, accuracy CL, and accuracy time evaluated comprehension. *Accuracy* was the proportion of correct responses that the participants provided to each expository MG’s trio of multiple-choice comprehension questions. CL was recorded after each comprehension question was answered. The CL measurements associated with a given MG’s trio of comprehension questions were averaged in accordance with the advice of van Gog et al. (2012) which produced *accuracy CL*. *Accuracy time* was the amount of time participants spent answering an MG’s set of comprehension questions.

### Table 1

*Dependent variables and their associated instruments*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation quality preferences</td>
<td>One’s preferences about the desirability and predicted effectiveness of realism, complexity, and 3D during the MG viewing experience.</td>
<td>Preliminary demographic survey.</td>
</tr>
<tr>
<td>Intuition</td>
<td>One’s expectancy about graphics.</td>
<td>Intuition rating trial.</td>
</tr>
<tr>
<td><strong>Intuition helpfulness</strong></td>
<td>One’s prediction about the efficacy of their intuition.</td>
<td>Intuition rating trial.</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Intuition time</strong></td>
<td>Amount of time taken to make an intuition.</td>
<td>Measured in seconds.</td>
</tr>
<tr>
<td><strong>Initial recurrence rate</strong></td>
<td>Proportion of the same intuitions made over IRT1 and IRT2.</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary recurrence rate</strong></td>
<td>Proportion of the same intuitions made over IRT2 and IRT3.</td>
<td></td>
</tr>
<tr>
<td><strong>MG choice</strong></td>
<td>Choice of what expository MG was viewed.</td>
<td>MG selection trial.</td>
</tr>
<tr>
<td><strong>Actual helpfulness</strong></td>
<td>One’s assessment of the efficacy of the expository MG that they have just viewed.</td>
<td>MG selection trial.</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>Proportion of correct responses to comprehension questions.</td>
<td>Trio of comprehension question following each expository MG.</td>
</tr>
<tr>
<td><strong>Accuracy CL</strong></td>
<td>Amount of mental effort exerted in answering comprehension questions.</td>
<td>9-pt CL scale.</td>
</tr>
<tr>
<td><strong>Accuracy Time</strong></td>
<td>Amount of time taken to answer comprehension questions.</td>
<td>Measured in seconds.</td>
</tr>
</tbody>
</table>

**Procedure**

The study was conducted in a computer lab equipped with Apple iMac desktop computers. The participants completed the preliminary demographic survey before being randomly assigned to one of the study’s three conditions (HL, LH, or choice). Thirty-three participants were assigned to the choice condition, 27 participants were assigned to the HL condition, and 36 participants were assigned to the LH condition. Next, they
completed the first intuition rating trial. Participants in the HL and LH conditions then viewed the first expository graphic that was assigned to them, answered its trio of comprehension questions, and reported the actual helpfulness of the MG: HL participants viewed a high fidelity MG and LH participants viewed a low fidelity MG. However, participants in the choice condition completed the first part of an MG selection trial, chose what type of expository graphic they wanted to view, watched their chosen graphic in its entirety, answered the graphic’s set of comprehension questions, and completed the second part of their MG selection trial. Next, all of the participants finished the second intuition rating trial. Participants in the HL and LH conditions then viewed the second expository MG that was assigned to them, answered its trio of comprehension questions, and reported the actual helpfulness of that MG: HL participants viewed a low fidelity MG and LH participants viewed a high fidelity MG. Again, participants in the choice condition were able to choose what type of graphic they wanted to view: they completed the first part of another MG selection trial, chose and viewed an expository graphic, answered its comprehension questions, and finished the second part of their current MG selection trial. Lastly, all of the participants completed the third intuition rating trial (refer to Figure 2). On average the participants finished the study within 583.75 seconds (or approximately 10 minutes).

Results

Presentation Quality Preferences

The participants’ ratings of the presentation quality attributes of realism, 3D, and complexity were evaluated using a multivariate analysis of variance (MANOVA). All of
the attributes were found to be desirable and complexity was the only attribute that the participants predicted would not be effective for their MG viewing experience. Table 2 displays the mean ratings of the presentation quality attributes by condition. A 3 X 3 MANOVA was used to examine whether the experimental conditions produced any differences between the desirability of the attributes and how effective the attributes were predicted to be. Condition and the participants’ presentation quality preferences did not interact to produce any differences between the desirability and predicted effectiveness of any of the attributes, Wilk’s Λ = .96, F(6, 176) = .65, p = .69, and condition alone did not produce any differences between the desirability and predicted effectiveness of the attributes, Wilk’s Λ = .96, F(6, 176) = .55, p = .77. Regardless of condition the participants did find some of the attributes to be more desirable than potentially effective and vice versa, Wilk’s Λ = .77, F(3, 88) = 8.67, p < .001. Specifically, the desire for complexity outweighed its predicted effectiveness, F(1, 90) = 14.48, p < .001, partial η² = .14, whereas the desire for realism was exceeded by its anticipated utility, F(1, 90) = 13.71, p < .001, partial η² = .13. There was no difference between the desirability and predicted effectiveness of 3D, F(1, 90) = 3.12, p = .08, partial η² = .03. Also, realism was found to be the most desired and potentially effective attribute.

Table 2
Overview of participants’ presentation quality preferences by condition

<table>
<thead>
<tr>
<th>Desirability</th>
<th>Predicted Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realism</td>
<td>3D</td>
</tr>
<tr>
<td>Realism</td>
<td>3D</td>
</tr>
</tbody>
</table>
Intuition

The statistical approach taken to analyze the participants’ intuitions was generalized linear mixed modeling since intuition was a dichotomous categorical variable that was repeatedly measured throughout the study. Condition and exposure did not interact to produce an effect on intuition, $F(2, 279) = 1.90, p = .11$. Although condition alone had no effect on intuition, $F(4, 279) = .26, p = .77$, it was evident that the participants’ intuitions favoring high fidelity MGs spiked within the HL and LH conditions at the second intuition rating trial (see Figure 3). At the final intuition rating trial the choice condition saw the sharpest drop or decrease in intuitions favoring high fidelity MGs. Exposure did have a significant effect on the participants’ intuitions, $F(2, 279) = 7.50, p = .001$. Generally, there was a 25% increase in the participants’ intuitions for high fidelity MG between the first and second intuition rating trials, and then a 13.6% increase in those types of intuitions between the second and final intuition rating trials.

Note. All standard deviations are displayed in parentheses next to their respective means.

---

2 Generalized linear mixed modeling is a statistical procedure than enables an outcome or dependent variable (DV) to be linked to single or multiple independent variables (IVs) for the purpose of data analysis regardless of the innate sampling distribution, scale, or level of measurement of the DV. In the case of this paper's experiment the author used generalized linear mixed modeling to analyze repeated measurements of a binary categorical DV which adhered to a binomial sampling distribution and was linked to the IVs of interest via a logit link function. Please see Heck, Thomas, and Tabata (2012) for a thorough introduction and review of generalized linear mixed modeling for categorical DVs.
Table 3
Overview of results from mixed ANOVAs on the quality of participants’ intuitions

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Level of Analysis</th>
<th>df1, df2</th>
<th>F</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intuition Helpfulness</td>
<td>Condition X Exposure</td>
<td>3.62, 164.59</td>
<td>2.65*</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>2, 91</td>
<td>0.39</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Exposure</td>
<td>1.81, 164.59</td>
<td>1.76</td>
<td>0.02</td>
</tr>
<tr>
<td>Intuition Time</td>
<td>Condition x Exposure</td>
<td>4, 182</td>
<td>0.80</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>2, 91</td>
<td>0.08</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Exposure</td>
<td>4, 182</td>
<td>15.07***</td>
<td>0.14</td>
</tr>
</tbody>
</table>

*Note. This table explicitly lists the degrees of freedom due to the Greenhouse-Geisser approximations required; *p < .05, **p < .01, ***p < .001.

Intuition helpfulness and intuition time served as indicators of the quality of the participants’ intuitions (see Figures 4 and 5). According to 3 X 3 mixed ANOVAs there was an interaction between condition and exposure on intuition helpfulness where participants in the LH group exhibited a greater amount of confidence or certainty in their second intuition than in their final intuition and Table 3 displays these results. The HL participants’ confidence in their intuitions steadily rose throughout the study but the choice participants’ intuition helpfulness followed a trend similar to the LH condition. All the conditions observed a consistent decrease in intuition time during the study (i.e., all of the participants made their intuitions quicker as the study progressed).
Naïve Realism and Recurrence Rates

Overall, there was a high percentage of participants that exhibited naïve realism regardless of the condition to which they were assigned meaning that condition had no effect on intuition trend, $\chi^2(2, N = 96) = 2.23, p = .33, \phi = .15$, although participants in this study were 4.99 times as likely to be naïve than non-naïve (see Figure 6). The HL condition had the highest concentration of naïve participants out of all three conditions and within each condition the odds of participants being naïve were as follows: participants in the choice condition were 3.13 times as likely to be naïve than non-naïve, participants in the HL condition were 5.76 times as likely to be naïve than non-naïve, and participants in the LH condition were 7.51 times as likely to be naïve than non-naïve.

The initial recurrence rate and the secondary recurrence rate provided information about the prevalence and persistence of the participants’ intuitions because the recurrence rates consisted of successive intuitions. The vast majority of recurrent intuitions for both the initial recurrence rate and the secondary recurrence rate favored high fidelity graphics.
regardless of condition (see Figure 7). A generalized linear mixed model indicated that condition and exposure did not interact to affect the recurrence rates, $F(2, 186) = 2.88, p = .058$. Condition did not have an effect on the recurrence rates either, $F(2, 186) = .27, p = .76$. Nevertheless, exposure impacted the recurrence rates such that the recurrence of the participants’ intuitions favoring high fidelity graphics increased by 13.6% between the initial and secondary recurrence rates, $F(1, 186) = 4.62, p = .033$. The initial recurrence rate was highest for the choice condition and the secondary recurrence rate was highest for the HL condition which also observed a 33.3% increase in recurrent intuitions.

Figure 6. Participants’ intuition trends broken down by condition.

Figure 7. Participants’ initial recurrence rate (RR1) and secondary recurrence rate (RR2) broken down by condition.

Exposition

Before describing the exposition results it is necessary to present the decisions made by the choice condition’s participants (i.e., their MG choice). At each opportunity to choose and view graphics the choice condition participants mostly chose high fidelity expository MGs. At their first opportunity 93.9% of the choice condition participants
chose to view a high fidelity expository graphic and at the second opportunity 87.9% of them chose to view a high fidelity expository graphic. Figures 8, 9, and 10 display the participants’ accuracy, accuracy CL, and accuracy time, respectively. For exposition a 3 X 3 MANOVA indicated that condition did not interact with exposure to produce an effect on the variables of accuracy, accuracy time, and accuracy CL, Wilk’s Λ = .94, $F(6, 168) = .85, p = .53$, nor did it have any impact on the exposition variables by itself, Wilk’s Λ = .98, $F(6, 168) = .27, p = .95$. Exposition was affected by exposure, Wilk’s Λ = .80, $F(3, 84) = 6.95, p < .001$, as indicated by the overall increase in accuracy that the participants achieved after viewing their second expository MG, $F(1, 86) = 5.09, p = .027$, partial $\eta^2 = .06$, as well as the overall reduction in accuracy time (or latency), $F(1, 86) = 10.09, p < .001$, partial $\eta^2 = .11$, and accuracy CL imposed by the second expository MG, $F(1, 86) = 9.24, p < .001$, partial $\eta^2 = .13$. Also, the participants felt that the second expository graphic that they viewed was more helpful in presenting exposition and facilitating comprehension than the first expository graphic (see Figure 11). Specifically, actual helpfulness was only influenced by exposure $F(1, 87) = 37.26, p < .001$, partial $\eta^2 = .30$, but not by condition, $F(2, 87) = 1.28, p = .26$, partial $\eta^2 = .03$, or any interaction between condition and exposure, $F(2, 87) = .14, p = .85$, partial $\eta^2 = .00$. 
Discussion

The results yielded by this study provide insight into the MG viewing experience and answers to the research questions posed by the author. All three of the conditions that were compared contained at least one opportunity for the participants to have exposure to
complex animation via an expository graphic and several measures allowed the effects of complex animation to be iteratively observed. Each of the research questions inquired about different yet complimentary aspects of the MG viewing experience with the objective of articulating an efficient way to implement complex animation within a graphic and facilitate exposition. RQ1 focused on the exhibition of naïve realism whereas RQ2 focused on how the content presented by graphics was processed and comprehended. RQ3 addressed how the presentation of complex animation interacted with exposition throughout the entire MG viewing experience.

RQ1 concerned the stability and quality of the participants’ intuitions about expository MGs containing complex animation. Exposure was primarily responsible for the discernable differences between the variables associated with the participants’ intuitions whereas the three viewing scenarios (i.e., conditions) were not. A vast majority of the participants exhibited naïve realism regardless of the condition to which they were assigned and the participants’ confidence in their intuitions coincided with the fluctuations in their intuition choices. Also, the participants became quicker at making their intuitions over time. Generally, all of the conditions exacerbated naïve realism and none of them mitigated it. Interestingly, the recurrence of naïve intuitions significantly increased as the study progressed (i.e., the secondary recurrence rate was higher than the initial recurrence rate) which indicates that the persistence of naïve intuitions grew as the participants continued to receive exposure to expository MGs. It is possible that participants began to refine their conceptualizations of the content and complex animation presented by the expository graphics that they viewed which reinforced their intuitions. Considering that the participants were 4.99 times as likely to exhibit naïve
realism than not, it would appear that constant exposure to MGs affords a viewer the opportunity to adapt their mental model to the extent that it remains useful. A better understanding of how the participants developed mental models from the expository MGs and utilized them can be gained by answering the second research question.

**RQ2** dealt with the acquisition, processing, and application of information from the MGs presented to the participants. Again, condition had no effect. The participants achieved higher comprehension with the second expository graphic that they viewed and they also found it to be more helpful than the first expository graphic. It should also be noted that second expository MG viewed by all participants in the LH condition and almost all of the participants in the choice condition was a high fidelity MG. This would suggest that 67.71% of the entire study’s participants demonstrated efficient comprehension directly after viewing an MG containing complex animation and repeated exposure to MGs was the primary underlying cause. Efficient comprehension is characterized by high accuracy, low accuracy CL, and low accuracy time (cf. Paas & van Merriënboer, 1993; Hoffman & Schraw, 2010). As successive exposure to MGs occurs a viewer is able develop a precise conceptualization of an MG’s content and the complex animation depicting it by recognizing task relevant information through the MG’s visual clutter. Next, they evaluate the rigor of their mental model during task performance, acknowledge the mental model’s suitability, and make any necessary adjustments to the mental model and how new information is being assimilated into it. In brief, no specific condition was more or less conducive than another for comprehension.

**RQ3** had a much broader scope than the preceding research questions because RQ3’s query considered the overall effect of complex animation and the impact of its
presence during the MG viewing experience. During the present study every participant received at least one opportunity for exposure to an expository graphic containing complex animation and the author observed that participants exhibited a better understanding of the exposition provided by the high fidelity MG if they had already viewed and experienced task performance with another expository graphic. This occurred within all of the conditions which indicates that complex animation facilitates exposition if a viewer has continual exposure to MGs because they exhibit better task performance as time progresses. The logic surrounding this finding pertains to the development of one’s mental model – within the MG viewing experience exposition is amplified when complex animation is presented after a viewer has had the chance to establish a mental model which can then be reinforced by intuition(s) as well as adapted as more MGs are viewed. This is similar to the effects associated with media priming (Roskos-Ewoldsen, Roskos-Ewoldsen, & Carpentier, 2009). The finding also suggests that if viewers are going to be exposed to multiple graphics the initial graphic should not contain much complex animation but the subsequent MGs should. This heuristic would form the basis for optimizing an MG viewing scenario and providing individuals with the best MG viewing experience possible. The framework proposed at the beginning of the paper can now be updated to reflect the study’s results. The theory of naïve realism still accounts for the viewer’s external interaction with an MG and cognitive load theory still explains how the MG’s exposition is processed but now excessive detail in the form of complex animation does not have to be considered as a detriment to viewers if it is presented in ways that accommodate the development of mental models.
This study had a few limitations, which included the sample size and the quantity and homogeneity of the expository MGs employed. Although the study utilized 96 participants it may have been necessary to include more participants in order to increase the study’s power to detect more differences and interaction between the conditions and exposure. Also, the alternating MG viewing patterns of the HL and LH conditions could have been better contrasted if more viewing conditions had been incorporated into the study. Lastly, there were only two opportunities for participants to view expository graphics in the study but future research should offer more opportunities to do so in order to fully understand the persistence of certain intuitions.

This paper makes several contributions to the sparse body of research literature surrounding expository MGs. It explored the efficacy of a variety of viewing scenarios and established the significance of complex animation within the MG viewing experience. Proceeding forward research should begin to focus on the ways in which the narrative structure of graphics can be manipulated for the benefit of viewers and future investigations should evaluate the efficacy of entertainment graphics.
References


Marschark (Eds.), *Models of visuospatial cognition* (pp. 90-127). New York: Oxford University Press.


