Kaluga, Slava; Chandler, Paul; Sweller, John (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology* 1999(13), 351-371.

This article reports on two experiments which investigated alternatives to split-attention instructional designs. It was assumed that because a learner has a limited working memory capacity, any increase in cognitive resources required to process split-attention materials decreases resources available for learning. Using computer-based instructional material consisting of diagrams and text, Experiment 1 attempted to ameliorate split-attention effects by increasing effective working memory size by presenting the text in auditory form. Auditory presentation of text proved superior to visual-only presentation but not when the text was presented in both auditory and visual forms. In that case, the visual form was redundant and imposed a cognitive load that interfered with learning. Experiment 2 ameliorated split-attention effects by using color coding to reduce cognitive load inducing search for diagrammatic referents in the text. Mental load rating scales provided evidence in both experiments that alternatives to split-attention instructional designs were effective due to reductions in cognitive load. Both Slava Kaluga and John Sweller have conducted numerous experiments in the field of the effects of rich media on cognitive load. These two experiments support work done by others including Mayer, but also adds a twist by attempting the use of color coding to reduce cognitive load.

Kaluga, Slava (2007). Expertise reversal effect and its implications for learner-taylored instruction. *Educational Psychology Review*, 2007(19), 509-539.

Kaluga reviews past experiments which demonstrated the interactions between levels of learner prior knowledge and effectiveness of different instructional techniques and procedures have. This is a key cognitive theory which has been intensively investigated

within a cognitive load framework since mid-90s. This line of research has become known as the expertise reversal effect. Apart from their cognitive load theory-based prediction and explanation, patterns of empirical findings on the effect fit well those in studies of Aptitude Treatment Interactions (ATI) that were originally initiated in mid-60s. This paper reviews recent empirical findings associated with the expertise reversal effect, their interpretation within cognitive load theory, relations to ATI studies, implications for the design of learner-tailored instructional systems, and some recent experimental attempts of implementing these findings into realistic adaptive learning environments. This article fits well with my research paper as it ties together many cognitive concepts and discuss their develop over the years.

Kim, S.; Yoon, M; Whang, S.M.; Tversky, B.; Morrison, J.B. (2007). The effect of animation on comprehension and interest. *Journal of Computer Assisted Learning*, 2007(23), 260-270. Kim and company felt that although animations are believed to be effective in learning and teaching, several studies have failed to confirm this. Nevertheless, animations might be more attractive and motivating. So they conducted experiments using Fourth and sixth grade students who learned the operation of a bicycle pump from graphics that were: (i) presented simultaneously; (ii) presented successively; (iii) self-paced, or (iv) animated. The presentation mode affected evaluation of perceived comprehensibility, interestingness, enjoyment and motivation, but not comprehension test score. Fourth graders who were low in need for cognition rated the animations as more enjoyable and motivating, whereas sixth graders rated self-paced graphics as more interesting and motivating. The evaluations of sixth graders correspond to results of many studies on learning. Animations are not more effective than equivalent static graphics in learning,

and they are not seen as more motivating by sixth graders. This study is useful because it helps prove many of the multimedia theories developed by Mayer and expands upon them as well by adding the interest factor.

Meyer, Richard E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist*, 32(1), 1-19.

In this article, Dr. Richard Mayer, Professor at U.C. Santa Barbara asks how can we help students to understand scientific explanations of cause-and-effect systems, such as how a pump works, how the human respiratory system works, or how lightning storms develop. His answer is that one promising approach involves multimedia presentation of explanations in visual and verbal formats, such as presenting computer-generated animations synchronized with computer-generated narration or presenting illustrations next to corresponding text. In a review of eight studies concerning whether multimedia instruction is effective, there was consistent evidence for a multimedia effect: Students who received coordinated presentation of explanations in verbal and visual format (multiple representation group) generated a median of over 75% more creative solutions on problem-solving transfer tests than did students who received verbal explanations alone (single representation group). In a review of 10 studies concerning when multimedia instruction is effective, there was consistent evidence for a contiguity effect: Students generated a median of over 50% more creative solutions to transfer problems when verbal and visual explanations were coordinated (integrated group) than when they were not coordinated (separated group). Finally, in a review of six studies concerning for whom multimedia instruction is effective, Attribute x Treatment interactions indicated that multimedia and contiguity effects were strongest for low prior knowledge and high

spatial ability students. Results are consistent with a generative theory of multimedia learning in which learners actively select, organize, and integrate verbal and visual information. Dr. Richard Mayer is one of the renowned experts conducting research into the effects of multimedia on learning and the results of those studies are some of the most cited works in the field.

Mayer, Richard E.; Heiser, Julie; Lonn, Steve (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology*, 93(1), 187-198.

In 4 more Mayer experiments, college students viewed an animation and listened to concurrent narration explaining the formation of lightning. When students also received concurrent on-screen text that summarized (Experiment 1) or duplicated (Experiment 2) the narration, they performed worse on tests of retention and transfer than did students who received no on-screen text. This *redundancy effect* is consistent with a dual-channel theory of multimedia learning in which adding on-screen text can overload the visual information-processing channel, causing learners to split their visual attention between 2 sources. Lower transfer performance also occurred when the authors added interesting but irrelevant details to the narration (Experiment 1) or inserted interesting but conceptually irrelevant video clips within (Experiment 3) or before the presentation (Experiment 4). This *coherence effect* is consistent with a seductive details hypothesis in which the inserted video and narration prime the activation of inappropriate prior knowledge as the organizing schema for the lesson. This article covers 2 more cognitive theories proven by Mayer's experiments, the redundancy effect, which is consistent with Paivio's dual coding theory, and the coherence effect.

Mayer, Richard E.; Moreno, Roxana (2002). Animation as an aid to multimedia learning. *Educational Psychology Review*, 14(1), 87-99.

In this review, Mayer and Moreno, examine the role of animation in multimedia learning (including multimedia instructional messages and mircoworld games). They also present a cognitive theory of multimedia learning and summarize their program of research which has yielded seven principles for the use of animation in multimedia instruction. These principles include: the multimedia principal (present animation and narration rather than narration alone), spatial contiguity principle (present on-screen text near rather than far from corresponding animation), temporal contiguity principle (present corresponding animation and narration simultaneously rather than successively), coherence principle (exclude extraneous words, sounds and video), modality principle (present animation and narration rather than animation and on-screen text), redundancy principle (present animation rather than animation, narration, and on-screen text), and personalization principle (present words in conversational rather than formal style). This article adds animation to the mix of multimedia methods examined by Mayer in his previous experiments.

Moreno, Roxana; Mayer, Richard E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology*, 91(2), 358-368.

This article describes a study conducted by Roxana Moreno and Richard E. Meyer in which students viewed a computer animation depicting the process of lightning. In Experiment 1, they concurrently viewed on-screen text presented near the animation or far from the animation, or concurrently listened to a narration. In Experiment 2, they concurrently viewed on-screen text or listened to a narration, viewed on-screen text

following or preceding the animation, or listened to a narration following or preceding the animation. Learning was measured by retention, transfer, and matching tests. Experiment 1 revealed a spatial-contiguity effect in which students learned better when visual and verbal materials were physically close. Both experiments revealed a modality effect in which students learned better when verbal input was presented auditorily as speech rather than visually as text. This study is important to my research because the results support 2 cognitive principles of multimedia learning, modality and spatial contiguity.

Moreno, Roxana; Mayer, Richard E. (2000). A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. In this report the authors tested the recommendation that adding bells and whistles (in the form of background music and/or sounds) would improve the quality of a multimedia instructional message. In 2 studies, students received an animation and concurrent narration intended to explain the formation of lightning (Experiment 1) or the operation of hydraulic braking systems (Experiment 2), for some students, the authors added background music (Group NM), sounds (Group NS), both (Group NSM), or neither (Group N). On tests of retention and transfer, Group NSM performed worse than Group N; groups receiving music performed worse than groups not receiving music; and groups receiving sounds performed worse (only in Experiment 2) than groups not receiving sounds. Results were consistent with the idea that auditory adjuncts can overload the learner's auditory working memory, as predicted by a cognitive theory of multimedia learning. This report is important to my research because the results support the cognitive theory known as the coherence effect.

Moreno, Roxana; Mayer, Richard E.; Spires, Hiller A.; Lester, James C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? Cognition and Instruction, 19(2), 177-213. This experiment proves that students learn better when being spoken to in their native tongue. College students (in Experiment 1) and 7th-grade students (in Experiment 2) learned how to design the roots, stem, and leaves of plants to survive in 8 different environments through a computer-based multimedia lesson. They learned by interacting with an animated pedagogical agent who spoke to them (Group PA) or received identical graphics and explanations as on-screen text without a pedagogical agent (Group No PA). Group PA outperformed Group No PA on transfer tests and interest ratings but not on retention tests. To investigate further the basis for this personal agent effect, we varied the interactivity of the agent-based lesson (Experiment 3) and found an interactivity effect: Students who participate in the design of plant parts remember more and transfer what they have learned to solve new problems better than students who learn the same materials without participation. Next, we varied whether the agent's words were presented as speech or on-screen text, and whether the agent's image appeared on the screen. Both with a fictional agent (Experiment 4) and a video of a human face (Experiment 5), students performed better on tests of retention and problem- solving transfer when words were presented as speech rather than on-screen text (producing a modality effect) but visual presence of the agent did not affect test performance (producing no image effect). Results support the introduction of interactive pedagogical agents who communicate with students via speech to promote meaningful learning in multimedia lessons. Pedagogical agents in this case are narration components spoken

with different ethnic accents. This is an interesting study that helps bring social awareness into the mix.

Paivio, Allan (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology*, 45(3), 255-287.

This review traces the highlights of research on imagery and verbal processes and the progressive translation of that empirical base into the dual coding theory (DCT) of memory and cognition. General and specific criticisms of the theory and research findings are also addressed, focusing especially on alternative views that emphasize abstract propositional representations as the basis of cognition. This article falls within the scope of my effects of rich media on cognition as it covers not only the effects that imagery and verbal input have on cognition, but also DCT is one of the seminal theories my paper is based on and Allan Paivio is one of the foremost authority on DCT and a forerunner in the field of cognitive load theory.