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ABSTRACT

Many studies have shown that children of various ages learn from educational television, but the studies have not explained how children extract and comprehend educational content from these television programs. This paper proposes a model, the "capacity model," that focuses on children's allocation of working memory resources while watching television. The model consists of a theoretical construct with three basic components (processing of narrative, processing of educational content, and distance--the degree to which the educational content is integral or tangential to the narrative), plus several governing principles that determine the allocation of resources between narrative and educational content. The paper reviews the empirical research for characteristics of both television programs and viewers that affect the allocation of resources under the model, as well as developmental influences on the relevant processing. Finally, the paper discusses implications of the model for the production of effective educational television. (Author/HTH)

A capacity model of children's comprehension of educational content on television

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Abstract

Many studies have shown that children of various ages learn from educational television, but they have not explained how children extract and comprehend educational content from these television programs. This paper proposes a model (the capacity model) that focuses on children's allocation of working memory resources while watching television. The model consists of a theoretical construct with three basic components (processing of narrative, processing of educational content, and distance -- i.e., the degree to which the educational content is integral or tangential to the narrative), plus several governing principles that determine the allocation of resources between narrative and educational content. A review of empirical research points to characteristics of both television programs and viewers that affect the allocation of resources under the model, as well as developmental influences on the relevant processing. Finally, implications for the production of effective educational television are discussed.

It is well established that children can and do learn from watching educational television. Significant, positive effects of exposure to educational television have been found among both preschool and school-age children in a broad variety of areas, including: language and literacy (e.g., Ball & Bogatz, 1970, 1973; Ball, Bogatz, Karazow, & Rubin, 1974; Bogatz & Ball, 1971; Children's Television Workshop, 1994; Rice, Huston, Truglio, & Wright, 1990; Wright, Huston, Scantlin, & Kotler, in press; Zill, in press), mathematics and problem solving (e.g., Ball & Bogatz, 1970; Bogatz & Ball, 1971; Hall et al., 1990; Harvey, Quiroga, Crane, & Bottoms, 1976; Peel, Rockwell, Esty, & Gonzer, 1987; Schauble & Peel, 1986; cf. Hall, Esty, & Fisch, 1990), science and technology (e.g., Cambre & Fernie, 1985; Clifford, Gunter, & McAleer, 1995; Fay et al., 1995; Johnston, 1980; Johnston & Luker, 1983; Wagner, 1985; cf. Fisch et al., 1995), civics and history (Calvert, 1995; Calvert & Tart, 1993; Noble & Osmond, 1981), and more general school readiness (e.g., Bogatz & Ball, 1971). Where measured longitudinally, some of these effects have been found to endure over a period of one to ten years (e.g., Bogatz & Ball, 1971; Huston, et al., in press; Wright et al., in press; Zill, in press).

While all of these studies show that children learn from television, however, they do little to explain how this learning occurs. A few theoretical approaches have been proposed to describe aspects of the processing that allows viewers to understand televised narratives (notably the model proposed by Anderson & Bryant [1983] and the work of Collins and his colleagues [e.g., Collins, 1983]), but almost no mechanisms have been proposed to explain how children extract and comprehend educational content from television. Perhaps the theory that has come closest to addressing this question is the model presented in a brief but thoughtful discussion by Clifford et al. (1995). Yet, although the Clifford et al. model touches on some of the concepts that will be discussed below, it draws only a broad distinction between "drama" and "factual" (i.e., educational) television programs. This presents a limitation for the Clifford et al. model, because many educational programs (e.g., Sesame Street, Ghostwriter) are narrative-based themselves, thus requiring both types of processing simultaneously.

While narrative and educational content may be intertwined in educational television programs, they are, in fact, two different things. Stated simply, this paper will use the term "narrative" to refer to the story presented in the program -- the sequence of events, the goals set and achieved by its characters, and so on. By contrast, "educational content" will refer to the underlying educational concepts or messages that the program is intended to convey, which can include aspects of both declarative knowledge (e.g., historical facts) and procedural knowledge (e.g., problem-solving strategies). To illustrate the distinction between narrative and educational content (and to see how both can be embedded in a single television program), consider an example taken from Cro, a television series whose educational content centered on science and technology. In one episode of Cro, the lead character wanted to learn how to play a musical instrument so that he could join a band; in the course of learning about different kinds of instruments, he learned that sound and music are caused by vibration, and that various kinds of instruments (i.e., string, wind, reed, percussion) vibrate in different ways. In this case, the narrative content of the episode revolved around the character's wanting to join a band and the events that led up to his learning how to play an instrument. The educational content of the episode, on the other hand, centered on sound and vibration.

The present paper represents a first attempt at a systematic model to explain how children extract and comprehend educational content from television. The model has its roots in the study of information processing (e.g., Kahnemann, 1973; Shiffrin & Schneider, 1977; Thomas, 1992). In particular, it grows out of the notion that much of the processing of complex stimuli takes place in working memory, but that the limited capacity of working memory places constraints on the amount and depth of processing that can occur simultaneously. Other aspects of information processing, such as the initial encoding of the complex stimuli presented by educational television, are also undoubtedly critical, but are beyond the scope of this paper.

The Model

Several studies have demonstrated that, as in the case of other complex stimuli, viewers' comprehension of television involves processing that draws on the limited capacity of working memory. This draw on the capacity of working memory is reflected in longer response times and/or poorer performance in secondary tasks that are concurrent with viewing (Armstrong & Greenberg, 1990; Beentjes & van der Voort, 1993; Lang, Geiger, Strickwerda, & Sumner, 1993; Lorch & Castle, 1997; Meadowcroft & Reeves, 1989; Thorson, Reeves, & Schleuder, 1985). The demands of processing material on broadcast television are compounded by the very nature of the medium; unlike reading, a viewer's experience of television encompasses both visual and auditory information simultaneously, and it is not self-paced (Eckhardt, Wood, & Jacobvitz, 1991). Viewers of broadcast television cannot control the speed of the incoming information or review material that they have difficulty understanding (as is typically done in reading; cf. Pace, 1980, 1981). Instead, the processing that underlies their comprehension must be employed in such a way as to fit the pace of the television program.

Given the potential scale of the processing demands involved, it is not surprising that

Salomon (e.g., 1983, 1984) has posited -- and demonstrated -- that children's comprehension of print and audiovisual media is associated with their amount of invested mental effort (AIME), a construct that is clearly related to (if not synonymous with) the amount of working memory resources devoted to comprehension. When viewers expend greater AIME, according to Salomon, they process the televised information more deeply, and comprehension is enhanced.

However, while the amount of mental effort may be important, it is not a complete explanation when dealing with educational television. Because comprehension of educational television programs requires viewers to process both narrative and educational content simultaneously, we must consider, not only the amount of cognitive resources involved, but also the allocation of those resources among the two parallel processes. This point provides a central motivation for the model proposed below.

Specifically, the model described in this paper (henceforth referred to as the capacity model) revolves around the notion that a critical issue in the comprehension of educational television is the degree to which working memory resources are devoted to comprehension of narrative versus embedded educational content. The model is comprised of a theoretical construct and a set of governing principles that guide the allocation of resources among the components of that construct.

Theoretical Construct

Under the model, demands on capacity are seen to stem from three basic elements: (1) processing of narrative, (2) processing of educational content, and (3) the distance (d) between the two -- that is, the degree to which the educational content is integral or tangential to the narrative

(Fig. 1). In broad terms, the model argues that similar kinds of processing (e.g., accessing prior knowledge, drawing inferences) are employed, essentially simultaneously, in understanding both narrative and educational content on television. When the educational content is tangential to the central narrative of a television program, the two parallel processes of comprehension compete for limited resources in working memory. The result is that the educational content cannot be processed as deeply as it might otherwise be, and comprehension of the educational content (though perhaps not the narrative, as will be discussed in the "Governing Principles" section below) is likely to be impaired. On the other hand, when the distance between narrative and educational content is small (i.e., when the educational content is woven tightly into the narrative), then the two parallel processes become complementary rather than competitive, and comprehension is likely to be strengthened.

When the processing of narrative and educational content compete for resources in working memory, the scope of the competition depends on the level of the demands that each type of processing places on those resources -- that is, the amount of resources each requires. In general, the literature on information processing has shown that a greater amount of prior knowledge allows information to be integrated in larger chunks, and that familiar, well-practiced tasks can be performed more automatically, reducing the demands on working memory resources and allowing for more efficient use of parallel processes (e.g., Norman & Bobrow, 1976; Shiffrin & Schneider, 1977). Following from this tradition, the capacity model predicts that factors that allow for more efficient processing of either televised narrative or educational content (e.g., prior knowledge) will reduce the demands of processing that type of information.[1] Thus, competition is reduced, and the result is more efficient -- and effective -- parallel processing of narrative and educational content.

Fig. 1 about here

Let us consider each of the three components of the model in more detail, along with the contributing factors that determine its demands on working memory and empirical data that support them.

Processing of narrative. The presence of narrative is self-evident in the many educational television programs that employ fictional (or even factual) stories and characters. However, I would argue that all televised presentations of educational content also involve some form of narrative. This point is not limited only to the case of story-based educational television, such as the example from Cro discussed above, but applies to any program that portrays a series of events. To take an extreme example, even a televised lecture can be conceived of as containing some level of narrative, albeit a simple and rudimentary one (e.g., "First, he welcomed us and thanked us for watching. Then, while he talked, he drew some diagrams on the blackboard to show the structure of the atom. Then, he told us that next week, he'll talk about molecules, and that was the end.").

Of all of the components of the model, the processing of narrative is the one that has received the greatest attention in past literature and, thus, is the one about which we know the most. Both theory and empirical research have painted a picture of television viewers as actively constructing their understanding of televised narratives through many of the same processes used in reading, such as accessing prior knowledge and drawing inferences (e.g., Anderson & Bryant, 1983; Collins, 1983; Huston & Wright, 1997, pp. 1019-1020; Palmer & MacNeil, 1991; Pearl, Bouthilet, & Lazar, 1982, pp. 22-27). Much, if not all, of this processing would be presumed to take place in working memory, and therefore, would place demands on its limited resources.

The demands that narrative places on working memory resources are far from constant. Numerous factors have been shown to affect comprehension of televised narrative and, presumably, the demands of the processing that leads to that comprehension as well. These factors include characteristics of both the television program and the viewer (Fig. 2).

One important viewer characteristic that affects the demands of processing narrative is viewers' prior knowledge of the subject matter around which the narrative revolves; Newcomb and Collins (1979) found that children's comprehension of a televised narrative was enhanced when their ethnic and social class background matched that of the characters and situations portrayed in the program. Often, discussions of prior knowledge are framed in terms of the scripts and schemata stored in viewers' memories before they come to the program. The presence of elaborate schemata has been found to aid comprehension of narratives in text (e.g., Bower, 1978), and it is reasonable to expect that the same holds true for television. For example, it is probably easier for a viewer who knows a great deal about baseball (e.g., the rules of the game, the typical sequence of events in a game) to understand a television drama about a baseball game than it is for a viewer who has never seen a baseball game before. (Indeed, a text comprehension study by Spilich, Vesonder, Chiesi, & Voss [1979] found that baseball fans were better able to recall central information from a story about a baseball game than non-fans were.) The existence of prior knowledge allows the narrative to be assimilated into memory more easily, thus reducing the demands of processing.

A related viewer characteristic that can also reduce the demands of processing narrative is viewers' more general schemas regarding the structure of stories themselves. Research on text comprehension has shown story schemas (i.e., an understanding of the basic structure of stories as a hierarchical series of events) to aid in comprehension and recall of narratives (e.g., Thorndyke, 1977; cf. Mandler & Johnson, 1977). Within the context of television, a study by Meadowcroft and Reeves (1989) provides empirical evidence that advanced story schema skills are related to reduced processing effort, as well as increased memory for narrative and greater flexibility in the allocation of working memory resources across concurrent tasks.

Just as demands can be lessened by viewers' knowledge of the structure of stories, demands can also be lessened by knowledge of the conventions of television. Television conventions include "formal features" such as cuts, fades, and montage that convey narrative information in and of themselves. Facility in understanding these conventions allows viewers to more easily comprehend televised narratives (e.g., Huston & Wright, 1983; Smith, Anderson, & Fischer, 1985).

The demands of processing narrative can also be lessened by viewers' more general cognitive abilities. Verbal ability and visual short-term memory have been shown to contribute to viewers' comprehension of television, with researchers hypothesizing that these benefits are due to more efficient use of resources within working memory (Eckhardt et al., 1991; Jacobvitz, Wood, & Albin, 1991).

All of the above factors would be expected to increase comprehension by reducing working memory demands. However, viewer interest in the subject matter of the narrative would be expected to facilitate comprehension through a different means: by increasing the overall pool of resources dedicated to processing the program in general. Because more resources are available in this case, the expected result would be greater comprehension of the narrative, but also could include greater comprehension of the educational content as well. Indeed, studies involving educational texts (both expository and narrative texts) have shown significant correlations between interest in the topic of the text and recall of/learning from the text (Schiefele, 1998).

In addition to characteristics of the viewer, the demands of processing narrative can also be affected by characteristics of the television program itself. One such characteristic is the complexity of the narrative (often operationalized in terms of the number of events in a story and the connections among them; e.g., Mandler & Johnson, 1977; Rumelhart, 1975). Developmental research in text comprehension has found that young children can use schemata to process stories only when they are structured simply and clearly state causal linkages (Mandler & Johnson, 1977; cf. Meadowcroft & Reeves, 1989). Thus, narratives containing long and/or complex chain of events are likely to place greater demands on working memory resources, both because of the amount and complexity of material to be processed and because of the relative inaccessibility of schemata that might otherwise reduce those demands.

A related program characteristic is the degree to which the narrative conforms to the prototypic structure of story schemas. Just as children's knowledge of story schemas has been shown to be related to reduced processing effort (Meadowcroft & Reeves, 1989), it is reasonable to expect that this benefit would emerge only when the narrative conforms to the prototypic structure described by such schemas. Stories that depart greatly from this kind of structure are less likely to benefit from viewers' knowledge of story schemas, and indeed, the schemas might even interfere with comprehension in this case.

Other program characteristics that contribute toward the ease with which televised narratives can be comprehended include the degree to which narrative information is explicit or needs to be inferred (e.g., Collins, 1983) and the degree to which information is linear and temporally ordered (Collins, Wellman, Keniston, & Westby, 1978). Because inferences draw on working memory capacity, conditions that rely more heavily on inferences (e.g., implicit content, or viewers' attempts to make sense of scenes that are scrambled in time) are likely to require greater resources, so it is not surprising that comprehension would be weaker in these cases.

Finally, the demands of processing narrative are likely to be reduced through the use of advance organizers (i.e., cues presented early in the program to alert viewers as to its subject matter, such as previews of upcoming material). Because advance organizers can help to orient viewers by identifying the type of information that will be central (rather than peripheral) to the narrative, it seems likely that less resources would be needed for viewers to identify and extract this central information when it arises later in the program. As a result, it is not surprising that studies have shown advance organizers to result in greater comprehension of televised narratives (e.g., Calvert, Huston, & Wright, 1987).

Processing of educational content. Because the comprehension of educational content on television has received far less attention than comprehension of narrative in the literature, any discussion of factors that contribute to the demands of processing educational content is necessarily more speculative than the one presented above. Based upon the factors that have been shown to contribute to comprehension of narrative, however, several analogous factors seem likely to help determine the demands of processing educational content as well. As in the comprehension of narrative, these factors include characteristics of both viewers and the television programs themselves.

Among the characteristics of viewers, it seems reasonable to expect that just as prior knowledge relevant to the subject matter of a narrative facilitates comprehension of that narrative (Newcomb & Collins, 1979), prior knowledge or existing schemata regarding the educational content of a television program should reduce the demands for processing that educational content and enhance comprehension. Indeed, Eckhardt et al. (1991) found that adult viewers' delayed recall of the educational content in a televised drama about the Underground Railroad increased as a function of their prior knowledge about this topic. Moreover, this effect was additive to (i.e., independent from) a concurrent effect of viewers' verbal ability. If we imagine that verbal ability might have served to help reduce the demands of processing the narrative in the television program, while knowledge of the Underground Railroad helped to reduce processing demands for the educational content, it would make sense for the effects of knowledge and verbal ability to be additive rather than producing a significant interaction.

As discussed above, another viewer characteristics that is likely to contribute to the processing of educational content is viewer interest (Schiefele, 1998), which can cause viewers to dedicate a greater pool of resources to processing the program. This interest can be interest in either the subject matter of the narrative (in which case the educational content benefits from a greater pool of resources for the program in general) or in the educational content itself (in which case a greater proportion of those resources also may be allocated to the content). In fact, research on text comprehension may support the notion of these two different mechanisms. One text-based study of children's comprehension of and performance in mathematical word problems found that boys' comprehension of the word problems was enhanced if they were interested in the narrative context in which the problem was embedded (e.g., football); however, interest in the narrative context was not a significant factor in the performance of children who were interested in mathematics (Renninger, 1998). From the standpoint of the model, one might imagine that these data reflect two different mechanisms: Interest in the subject matter of the narrative context resulted in a greater pool of available resources (benefitting both comprehension of the narrative context and mathematical problem solving), while interest in mathematics resulted in more resources being allocated to the mathematical content of the problems, regardless of the size of the overall pool.

In addition to viewer characteristics, some of the program characteristics that would be expected to affect the resource demands for processing educational content are also analogous to characteristics that contribute to the demands of processing narrative. Just as the demands of processing narrative are expected to be lower if the complexity of the narrative is low and narrative information is explicit, one would expect the demands of processing educational content to be reduced if the presentation of the educational content is clear (i.e., if it is explained well and on an age-appropriate level) and if the content is made explicit within the program (e.g., by talking about the geometry involved in a basketball player's making a difficult shot, rather than simply showing the player make shot without any discussion).

Lastly, in the same way that advance organizers that highlight central narrative information can help viewers identify central content and comprehend the narrative (e.g., Calvert et al., 1987), one would expect that advance organizers focusing on educational content would have a parallel effect on processing demands for educational content. In this case, the advance organizers orient viewers toward the educational content and make it easier to extract this educational content from the narrative in which it is embedded. Thus, the demands of processing educational content would be expected to be reduced, and comprehension of the educational content would increase.

Distance. The notion of distance between the narrative and the educational content of an educational television program is one of the features that is unique to the capacity model. As noted above, "distance" refers to the degree to which the educational content is integral or tangential to the narrative, a concept that the Children's Television Workshop has dubbed "content on the plotline" (e.g., Fisch et al., 1995; Hall & Williams, 1993). An example of a large distance between narrative and educational content is provided by the episode of Cro discussed earlier, in which the narrative concerned learning how to play a musical instrument and the educational content concerned the notion that sound is caused by vibration. Although the narrative and the educational content of this episode were related (particularly since the episode showed the ways in which vibration is manifest in different musical instruments), they were not integral to each other, since a knowledge of vibration is not a necessary precursor to learning how to play a musical instrument.

By contrast, an example of a small distance between narrative and educational content can be found in a series of segments produced for the mathematics program Square One TV. The narrative in these segments concerned a pair of mathematical detectives who helped a young boy find a hidden treasure by figuring out a series of puzzles and clues, all of which were built around a mathematical sequence of numbers known as the "Fibonacci sequence."[2] Here, the educational content was far more integral to the narrative; without manipulating the mathematical sequence, the characters could not solve the puzzles, and thus could not find the treasure.

It seems reasonable to expect that when the distance between narrative and educational content is large, the two types of content must compete with each other for resources within working memory. Because similar kinds of processing are required to understand both narrative and educational content (e.g., accessing and forming connections to prior knowledge in long-term memory, drawing inferences), and because viewers would employ both types of processing concurrently, interference stemming from viewers' processing of the narrative would make the educational content less likely to be processed as deeply or thoroughly. The probable result would be that comprehension of the educational content would be weaker than it might be otherwise.

When the distance between narrative and educational content is small, however, a very different situation emerges. The intertwining of narrative and educational content in this case means that, rather than competing with each other for limited resources, the parallel processes responsible for comprehending narrative and educational content actually complement each other instead. For example, in the Square One TV material described above, the use of the Fibonacci sequence is essential in characters' movement from setting to attaining goals in the event structure of the narrative. Thus, the processing that allows viewers to understand the Fibonacci sequence while watching the program is not only part of their processing of educational content, but of their processing of the narrative as well.

On an empirical level, this construct predicts that (all other things being equal) comprehension of educational content on television will be stronger when the distance between narrative and educational content is small than when it is large. In fact, this prediction was confirmed in a summative study of Cro (Fisch et al., 1995). Data from this study showed that children who viewed Cro showed a significantly greater understanding of the technological principles presented than nonviewers did. However, this difference emerged only for two episodes in which the educational content was closely tied to the narrative; there was no difference for two other episodes, in which the educational content was more tangential to the narrative. (For similar data in the area of literacy, see Hall & Williams, 1993). Indeed, although no controlled comparison was made to material in which distance was larger, it is also worth noting that a separate study found that after viewing the Square One TV material discussed above (in which distance was small), many eight- to twelve-year-old children were able to describe and/or explain the Fibonacci sequence as much as two weeks later (Square One TV Research, 1988).

Governing Principles

To some degree, the allocation of working memory resources between the processing of narrative and educational content is a function of the demands of each. However, the capacity model also specifies several broad governing principles that also help to determine the differential allocation of resources among the processing of narrative and educational content.

Narrative dominance. The first of these principles is that, as a default, the model posits that priority is given to comprehension of narrative over educational content (a principle I refer to as narrative dominance). For this reason, when the processing of narrative and educational content are in competition with each other -- when distance is large or the demands of processing narrative and/or educational content are high -- a greater proportion of working memory resources will be devoted to the narrative than the educational content (although the allocation of resources is also subject to some degree of voluntary control, as discussed below).

There are two chief reasons to believe that this is the case. First, television is primarily an entertainment medium. Although Greenberg (1974) found, when asking children about their reasons for watching television, that approximately 20% of the variance was attributable to social learning, the remainder centered on entertainment functions: relaxation, habit, arousal, forgetting problems, killing time, and alleviating boredom. Given that children's comprehension of television is affected by whether they are watching to learn or to have fun (Salomon & Leigh, 1984), it seems reasonable to think that at least part of this effect is due to the allocation of resources in working memory. Thus, if viewers' primary reason for watching television is entertainment (and since the entertainment value of a program is likely to lie in its narrative), it seems likely that, all other things being equal, the default would be for viewers to devote a greater proportion of working memory resources to processing narrative.

Second, if we think of an educational television program as having "surface" (i.e., explicit) content and "deep" (i.e., more implicit) content, it is likely that the narrative will comprise the surface content while the educational content may lie more deeply within the program. While educational content may be embedded within a narrative (as in the examples from Cro and Square One that were presented earlier), it is difficult to imagine how one might construct a television program in which the opposite is true (i.e., the narrative is embedded within educational content). Even if the educational content is fairly explicit within the narrative, it is still embedded within the narrative. All other things being equal, then, when only limited resources are available in working memory, it seems reasonable to expect that those resources would be devoted primarily to the surface content of the program -- that is, the narrative.

Indeed, although no empirical studies have tested the narrative dominance hypothesis directly, past research may provide some limited support for this principle. In a study of children's comprehension of several Square One TV segments, Peel et al. (1987) found that recall of the characters' problem and solution (the level most closely tied to narrative in the segments) was consistently higher than understanding of underlying mathematical concepts. When children comprehended only one aspect of the segments in this study, it tended to be aspects related to the narrative rather than the underlying educational content.

Relative availability of resources. In light of the principle of narrative dominance, the second governing principle is that the pool of resources available for processing educational content on television is a function of the amount of resources not already committed to the narrative. A basic concept in research in the field of information processing is that, when parallel process take place concurrently, less resources are available than if either process takes place in isolation (e.g., Norman & Bobrow, 1976; Shiffrin & Schneider, 1977). When the processing of narrative and educational content compete for resources, the model predicts that any deficit would be most likely to appear in the resources available for processing educational content.

In practice, the amount of resources available for processing educational content depends on both the factors that determine the demands of processing each type of content and the distance between them. When the demands of processing narrative are relatively low (e.g., when the narrative is fairly simple), more resources are available for processing of the educational content. Conversely, when the demands of processing educational content are relatively low (e.g., when the presentation of the content is clear), less of the working memory resources are needed, so the residual resources not consumed by processing the narrative may be sufficient. Finally, as discussed earlier, when the distance between the narrative and educational content is small, the processing of the two types of content become intertwined, so the resources devoted to one can also contribute to the processing of the other.

Thus, the strongest comprehension of educational content would be expected to be observed when the demands of processing both narrative and educational content are low, and the distance between them is small. The weakest comprehension would be expected when the demands of both types of processing are high, and the distance between them is large.

Voluntary allocation of resources. While narrative dominance may operate as a default, the capacity model also assumes that viewers can also choose to allocate resources differentially among the processing of narrative and educational content. This principle, too, has not been tested directly in past research. However, several studies have shown that a number of factors can affect, not only the amount of a televised narrative that is recalled, but also the level at which the narrative is understood. One such factor is viewers' reason for watching; studies by Kwaitek and Watkins (1981) and Salomon and Leigh (1984) both found that instruction to view for learning led to greater recall of televised material, including higher levels of abstraction. Another factor is parental commentary during co-viewing with their children; Collins, Sobol, and Westby (1981) found that facilitating commentary from parental co-viewers resulted in greater comprehension of implicit content among children. While one might argue that the facilitation of comprehension found by Collins et al. (1981) could be due to parents' comments making the implicit content more explicit, it is difficult to imagine an explanation of the Kwaitek and Watkins (1981) or Salomon and Leigh (1984) data that does not assume a differential allocation of working memory resources to the processing of implicit content. Indeed, research on text comprehension has indicated that providing college students with questions before they read a text results in more time spent (i.e., more resources devoted to) passages related to those questions (Reynolds & Anderson, 1982), suggesting that the parental comments in the Collins et al. study may have had a similar effect on viewers' allocation of resources.

Just as motivation and commentary affect the level on which narrative is comprehended, one might expect similar factors to lead viewers to allocate a greater proportion of resources to educational content as well. Thus, viewers' motivation to view a program for the purposes of learning, parental commentary, or any other factor that serves to make the educational content more salient in the mind of the viewer is likely to result in a greater proportion of working memory resources being allocated to educational content.

Finally, it is important to note that, although each of these considerations would be expected to increase the proportion of resources allocated to educational content, none of them would be expected to result in viewers' abandoning the processing of narrative altogether. The principle of narrative dominance, coupled with the notion that educational content is embedded more deeply in television programs than narrative is, implies that it would be difficult for viewers to extract and process educational content without also processing the narrative, at least to some extent. Rather, viewers' voluntary allocation of greater resources to educational content would be expected to increase the depth of processing of educational content and perhaps reduce (but not eliminate) the processing of narrative.

Developmental Aspects of the Model

Many studies have demonstrated that, barring ceiling effects, children's comprehension of both narrative and educational content on television increases with age (see Huston & Wright, 1997 for a recent review that includes numerous studies demonstrating age differences in comprehension of television). From the standpoint of the capacity model, these developmental trends raise questions as to the ways in which the processing described by the model changes with age.

In fact, both the literature on children's comprehension of television and the more general literature on information processing point to developmental trends in several factors that contribute to comprehension under the model. For the purposes of this discussion, these factors can be divided into two broad classes: (1) those that affect the demands of processing narrative and/or educational content, and (2) those that affect the allocation of resources in working memory.

Development and the Demands of Processing

Since the model assumes that comprehension of educational content is affected greatly by the demands of processing both narrative and educational content, developmental factors that serve to reduce these processing demands should also contribute to better comprehension of educational content. Several such factors have been identified in past literature.

Prior knowledge. Perhaps the most obvious developmental factor relevant to the capacity model is children's acquisition of increasing amounts of world knowledge as they get older. As discussed above, a greater amount of existing knowledge or more elaborate schemata for a particular topic allows new information to be assimilated more easily. Thus, as children gradually accumulate knowledge with age, this greater knowledge base would be expected to reduce the demands of processing new information. This would hold true for the processing of both narrative and educational content; prior knowledge or schemata relevant to a particular story would reduce the demands of understanding narrative, while prior knowledge relevant to the underlying educational content would reduce the demands of processing educational content.

Inferences. Another way in which prior knowledge plays a role is in facilitating the generation of inferences to aid in comprehension. Children's ability to draw inferences regarding televised narrative increases with age (Collins, 1983), and research on parallel effects outside the realm of television has suggested that this trend is due primarily to older children's having a greater knowledge base available to them (Omanson, Warren, & Trabasso, 1978). Although the use of inferences has been investigated primarily with regard to comprehension of narrative, it seems likely that knowledge relevant to the educational content of a television program would lead to a similar facilitation of inferences regarding that content. Despite the fact that the process of drawing such inferences itself requires working memory resources, the ability that it provides to anticipate information and fill in gaps seems likely to make the processing of both narrative and educational content more efficient on the whole. (And, indeed, children's ability to draw such inferences is likely to become more automatic and draw less on working memory resources as they get older, as discussed below.)

Formal features. In addition to knowledge about the subject matter of the narrative and about the educational content, knowledge about the conventions of television itself may also be relevant. Research has shown that children's understanding of the formal features of television increases with age (e.g., Huston & Wright, 1983). Since, as discussed above, a greater knowledge of formal features is associated with greater comprehension of televised narrative (e.g., Smith et al., 1985), this factor, too, may reduce the demands of processing narrative as children grow older. As children are able to devote less effort and resources to making sense of the conventions of television (e.g., uniting successive scenes), more attention can be given to the story -- and, perhaps, the educational content -- itself.

Automaticity. A long line of information processing research has indicated that, as cognitive tasks become more practiced, they also become more automatic and draw less on the resources of working memory (e.g., Shiffrin & Schneider, 1977). Given that American children spend a tremendous amount of time watching television -- estimated between 11 and 28 hours per week across studies (e.g., Anderson, Field, Collins, Lorch, & Nathan, 1985; Huston, Watkins, & Kunkel, 1989; Huston, Wright, Rice, Kerkman, & St. Peters, 1987) -- this represents time spent practicing all of the skills needed to understand televised narratives, such as decoding formal features, engaging in semantic and syntactic analyses, drawing inferences, and so on. Thus, one would expect that children's extensive experience in watching (and understanding) television programs would lead to a better and more automatic processing of televised narrative as they get older. If we add to this body of experience the time children spend reading and listening to stories that are not on television, the likelihood that their processing of narrative becomes more automatic with age increases exponentially.

At the same time, children's vast experience with educational content in both formal (i.e., school) and informal settings makes it likely that the processing of educational content, too, becomes increasingly automatic with age. Together, the greater automaticity of processing both narrative and educational content reduces the demands of each kind of processing, thus allowing for an easier management of resources across the two.

Development and the Allocation of Resources

Apart from the above factors, which reduce the demands of processing narrative and/or educational content as children grow older, research has also pointed to aspects of working memory itself that develop with age. Even assuming a constant level of demands from the dual processing of narrative and educational content, these aspects of development would contribute to more efficient management of those parallel processes, and thus, greater comprehension of educational content (and, perhaps, narrative as well).

Speed of processing. Developmental research has shown that, as children mature, they can hold increasing amounts of information in working memory (Dempster, 1981; Gathercole & Baddeley, 1993). Research by Kail (1992; Kail & Park, 1994) and Fry and Hale (1996) has suggested that this improvement is due, not to an increase in the capacity of working memory itself, but to a developmental increase in the speed of information processing within working memory. Faster information processing allows for more efficient use of the limited resources available in working memory.

Particularly within the realm of television, where (unlike reading) the input of information is not self-paced, an increase in processing speed clearly would provide a great advantage. Such an increase would allow for more efficient and effective management of the parallel processing of narrative and educational content, and potentially, for deeper processing of each while viewing.

Management of multiple goals. A related factor may concern developmental changes in children's ability to manage multiple goals in working memory. Lawson and Kirby (1981) have demonstrated that the skill of managing multiple problem-solving goals in working memory can be taught, suggesting that this ability may increase with age and experience. (Consistent with this idea, Wickens [1974] found evidence of a developmental shift from "single channel" processing, in which children attend to only one thing at a time, to parallel processing, in which they can coordinate attention to multiple sources of information at the same time.)

If this ability does increase with age, then one benefit under the capacity model could be an increased ability to allocate working memory resources effectively, making it easier to process narrative and educational content concurrently. Indeed, since the skill of managing multiple goals in working memory can be taught, it is even possible that, within the realm of educational television, the ability to balance resources among processing of narrative and educational content would improve with practice. In other words, as children watch increasing amounts of educational television, their cumulative experience in processing narrative and educational content simultaneously could make it easier for them to balance these two types of processing when watching other educational television programs in the future. (Alternately, of course, it is also possible that such an effect might only be obtained with explicit training analogous to that used by Lawson and Kirby [1981].)

Conclusion

To summarize, the capacity model revolves around three basic components:

- Processing of narrative
- Processing of educational content
- Distance

The processing demands for comprehending narrative and educational content are affected by numerous factors, including: prior knowledge (of information relevant to the story and the educational content, as well as the formal features of television), the ability to engage in top-down processing and identify central information in the narrative, the complexity of the story, the need for inferences, the use of advance organizers, and the clarity of the presentation of educational content.

Allocation of working memory resources among the processing of narrative and educational content is determined by three governing principles:

1) As a default, priority is given to narrative over educational content (narrative dominance).
2) High demands of processing narrative leave less resources available for educational content, while low demands of narrative leave more resources available. A small distance between narrative and educational content reduces the degree to which they must compete for

limited resources.

3) Resources also can be allocated voluntarily, depending on a variety of factors (e.g., reason for viewing, parental commentary during co-viewing), but processing of narrative is never abandoned entirely in favor of educational content.

Based upon these components and governing principles, there are five ways in which comprehension of educational content can be increased: (1) by increasing the total amount of working memory resources devoted to understanding the television program as a whole (akin to Salomon's [1983] theory of AIME), (2) by reducing the demands of processing narrative, so that more resources are available for processing educational content, (3) by reducing the demands of processing educational content, so that a smaller amount of resources is needed, (4) by minimizing the distance between narrative and educational content in the program (i.e., by making the educational content integral to the narrative) so that the two parallel sets of processing complement each other, rather than compete, and (5) via viewers' voluntary allocation of a greater proportion of working memory resources to the processing of educational content (e.g., because of a motivation to learn).

More specifically, the model gives rise to numerous empirical predictions regarding the conditions under which comprehension of educational content will be strongest. These conditions are summarized in Tables 1 and 2, and include characteristics of the program (Table 1) and of the viewer (Table 2). Some of these predictions are already supported by existing studies in the research literature (as noted throughout this paper), while further research will be needed to test others.

Tables 1 & 2 about here

Clearly, the fact that only some of these predictions have been tested means that the model holds numerous implications for future research. In addition, however, the model also holds more practical implications for the creation of effective educational television programs. By incorporating appropriate program characteristics, such as advance organizers or a small distance between narrative and educational content, into the design of material for educational television, producers may be able to maximize comprehension and impact of that material among its target audience. Indeed, several of these factors are already recognized and used by some television producers (e.g., Fisch & Truglio, in press; Hall & Williams, 1993). Hopefully, through the efforts of researchers in this field, these factors will be incorporated more broadly into the design of educational television programs, so that the benefit for the children who watch them can be made even more powerful.

Notes

1. It should be noted that, contrary to this general prediction, Lorch and Castle (1997) found that engagement of cognitive capacity was greater while viewing comprehensible segments of Sesame Street than when scenes were edited randomly or the audio track was made incomprehensible. However, the two positions can be reconciled easily. Lorch and Castle's comparison between material that is comprehensible or impossible to comprehend seems very different from a comparison between material that is merely easier or more difficult to comprehend. Based on the work of Allport (1989), Lang et al. (1993) have drawn a distinction between several different types of capacity limitations in watching television: those related to perceptual systems, attention or selection of stimuli to which viewers attend, and controlled processing (i.e., the ability to thoughtfully process and store information). The latter type of limitation is most relevant to the kinds of processing addressed by the capacity model, but the effects found by Lorch and Castle may rest in lower-level processing. Alternately, even if the same types of processing are involved, it may be that the relationship between comprehensibility and working memory resources is actually curvillinear, with viewers devoting minimal resources when material is incomprehensible (because they quickly give up), the greatest amount of resources when material is comprehensible but difficult to understand, and a relatively smaller amount of resources when material is familiar or easy to understand.

2. The Fibonacci sequence (1, 1, 2, 3, 5...) is derived by adding each two successive numbers to arrive at the next number in the sequence. For example, 1 + 1 = 2, 1 + 2 = 3, 2 + 3 = 5, and so on.

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Figure 1. Theoretical construct described by the capacity model (unelaborated version).

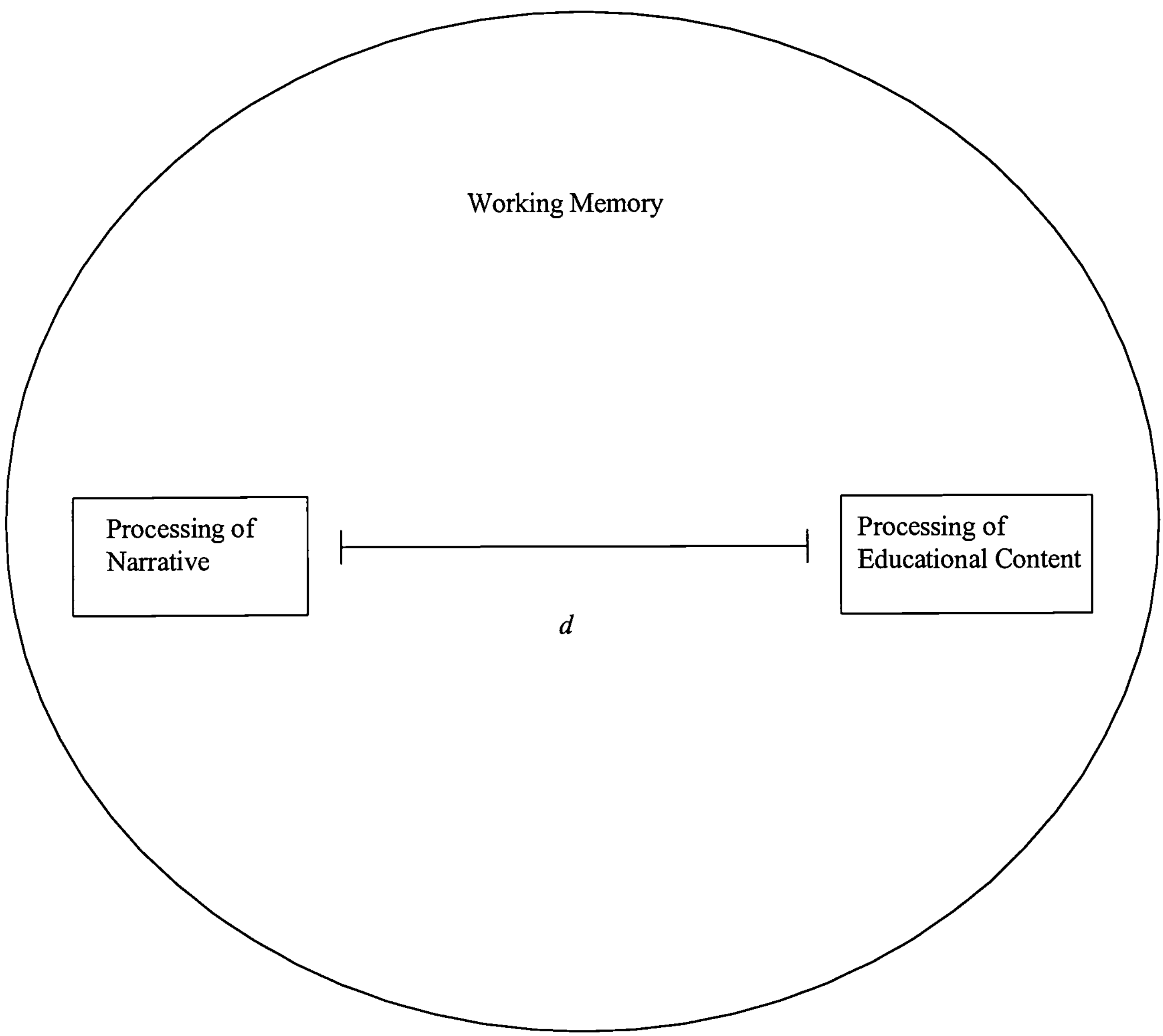
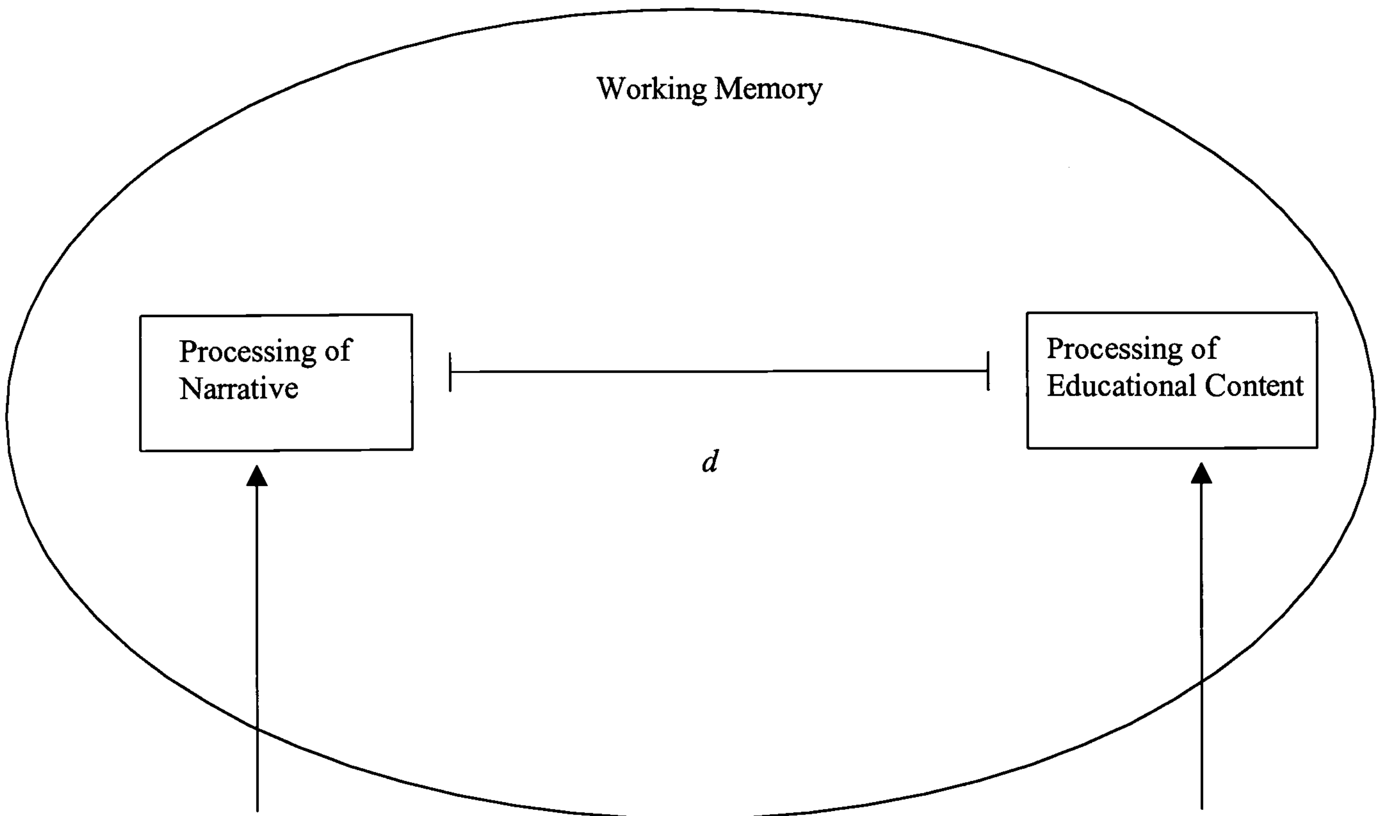


Figure 2. Theoretical construct described by the capacity model, with factors that determine the resource demands for comprehending narrative and educational content.



Affected by:

Viewer characteristics
Prior knowledge: story/characters
Story schemas
Knowledge/schemas: formal features
Interest in subject matter
Verbal reasoning ability
Short-term memory

Program characteristics
Complexity/coherence of story
Need for inferences
Fit to existing story schemas
Temporal organization
Advance organizers

Affected by:

Viewer characteristics
Prior knowledge of content
Interest in content

Program characteristics
Clarity of presentation
Explicitness of content
Advance organizers

Table 1. Predictions of the capacity model: Program characteristics resulting in greater comprehension of educational content.

Increase in:	**Underlying mechanism**
Simplicity of narrative	Decreased demands for processing narrative
Conformity to story schemas	Decreased demands for processing narrative
Temporal ordering	Decreased demands for processing narrative
Explicit links (vs. need for inferences)	Decreased demands for processing narrative
Advance organizers re: narrative	Decreased demands for processing narrative
Clarity of educational content	Decreased demands for processing educational content
Explicitness	Decreased demands for processing educational content
Advance organizers re: content	Decreased demands for processing educational content
Distance	Reduced competition between narrative & educational content

Table 2. Predictions of the capacity model: Viewer characteristics resulting in greater comprehension of educational content.

Increase in:	**Underlying mechanism**
Prior knowledge: story/characters	Decreased demands for processing narrative
Story schemas	Decreased demands for processing narrative
Knowledge of television conventions	Decreased demands for processing narrative
Verbal ability/ Verbal reasoning ability	Decreased demands for processing narrative and/or educational content
Short-term memory	Decreased demands for processing narrative and/or educational content
Prior knowledge: educational content	Decreased demands for processing educational content
Motivation to learn	Greater allocation of resources to educational content
Adult commentary re: educational content	Greater allocation of resources to educational content
Speed of processing	More efficient management of resources
Ability to manage multiple goals	More efficient management of resources
Interest in subject matter of narrative	Greater allocation of resources (in general)
Interest in educational content	Greater allocation of resources in general; greater allocation to educational content

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April 10, 1999

Dear Colleague:

It has come to our attention that you will be giving a presentation at the ***1999 Biennial Meeting of the Society for Research in Child Development*** to be held in Albuquerque, New Mexico, on April 15-18th. We would like you to consider submitting your presentation, or any other recently written education-related papers or reports, for possible inclusion in the **ERIC** database.

As you may know, **ERIC (the Educational Resources Information Center)** is a federally-sponsored information system for the field of education. Its main product is the **ERIC** database, the world's largest source of education information. **The Clearinghouse on Elementary and Early Childhood Education** is one of sixteen subject-specialized clearinghouses making up the **ERIC** system. We collect and disseminate information relating to all aspects of children's development, care, and education.

Ideally, your paper should be at least eight pages long and not have been published elsewhere at the time of submission. ***Announcement in ERIC does not prevent you from publishing your paper elsewhere*** because you still retain complete copyright. *The reproduction release is simply* ***ERIC's*** *way of stating the level of availability you want for your material.* Your paper will be reviewed and we will let you know within six weeks if it has been accepted.

Please complete the reproduction release on the back of this letter, and return it with an abstract and two copies of your presentation to ***BOOTH #19*** or to **ERIC/EECE**. If you have any questions, please contact me by email at (ksmith5@uiuc.edu) or by phone at (800) 583-4135. I look forward to hearing from you soon.

Best wishes,

Karen E. Smith

Karen E. Smith
Acquisitions Coordinator