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The impact of media literacy on children's learning from films and hypermedia

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ABSTRACT

Within the extensive literature on the role of educational media in children's learning and the factors influencing that learning, the possible impact of media literacy remains unexamined. The present study examines the influence of media literacy on learning from television and hypermedia environments. In a sample of 150 children with a mean age of 5.33, a computer-based test was used to assess media literacy, and recognition and inference questions were used to measure learning. The influence of intelligence, media usage, and socioeconomic status as independent variables was also assessed. Hierarchical regression analyses showed that media literacy was a significant predictor of learning from media, even when controlling for other relevant factors such as intelligence.

Ever since television and computers became widely available to a broad public, researchers have examined their effects on children's development. Both of these media have given rise to concerns based on assumptions or evidence of their negative influence on children's development in the suppression of other activities (Cantor, 2012; Koolstra, van der Voort, & van der Kamp, 1997) or in creating a disposition to aggressive behavior (Bushman & Huesmann, 2012). However, other research, focusing on the educational impact of media, suggests that well-designed and age-appropriate educative media can impart knowledge (e.g., Mares, Sivakumar, & Stephenson, 2015; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Aside from the characteristics of educational media that influence learning, researchers have also examined personal characteristics of learners such as demographics, age, and gender (for an overview, see Kirkorian & Anderson, 2008). The present study examines the effect of media literacy as another personal characteristic that has not to our knowledge been examined to date.

1. Media literacy

Definitions of media literacy change often as existing technologies evolve and new technologies appear (Guernsey & Levine, 2015). Such definitions usually include competencies like accessing, understanding, analyzing, and evaluating media messages; creating media messages; participating; and reflecting (e.g., Hobbs & Moore, 2013; Rogow, 2015). In the current article, we will depend mainly on Potter's (1998, 2013) concept of media literacy, as it adopts a developmental perspective. According to this conception, children between the ages of 3 and 5 years develop the so-called "rudimentary skills" of media literacy. Between 5 and 9 years, children begin to develop critical evaluation skills, which become ever more important in adolescence and adulthood, when "advanced skills" are acquired. Rudimentary skills relate to the fundamental capability to read media symbols, to recognize the patterns those symbols create, and to ascribe meaning to those patterns. We (Nieding & Ohler, 2008) encapsulated these abilities in the term *media sign literacy* ("Mediale Zeichenkompetenz") (p. 382), proposing that this is the most important aspect of media literacy development in young children.

1.1. Development of media sign literacy

The first milestone in the development of media sign literacy (MSL) is the ability to use symbols. This ability is closely linked to other developmental markers such as understanding of intentionality, mental states, cultural conventions, and iconicity (Namy & Waxman, 2005). The understanding that symbols (e.g., pictures or films) refer to something other than themselves is referred to as *representational insight* (DeLoache, 2002). International comparative studies have shown that this capability is not innate but is based on experience of pictures;

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infants in Western cultures show earlier understanding of the representational nature of pictures than children who have had no previous experience of pictures (Callaghan, Rochat, & Corbit, 2012; Walker, Walker, & Ganea, 2013). The way in which infants grasp at photographs as if they were objects (e.g., DeLoache, Uttal, & Pierroutsakos, 1998) is further evidence that infants do not yet understand that photographs are representational. By the age of 18 months, however, children rarely grasp pictures in this way; instead they begin to point and attempt to talk about the represented objects (Uttal & Yuan, 2014). However, the child's understanding of the representational nature of photographs is not fully developed at 18 months, as they have yet to learn exactly how photographs relate to their referents. Even 3-year-olds still make errors in this regard, believing for instance that photographs taken in advance will change if the represented scene changes (Donnelly, Gjersoe, & Hood, 2013). Similarly, 3-year-olds assumed that popcorn would spill out of a televised popcorn bowl if the television was turned upside down (Flavell, Flavell, Green, & Korfmacher, 1990). These and other results show that the development of representational insight follows a similar course for video as for still images; while 9-month old infants try to grasp objects on the screen, between 15 and 19 months of age, they will instead begin to point at the screen (Pierroutsakos & Troseth, 2003).

Note that our concept of media sign literacy is related to what DeLoache called "symbolic sensitivity"—"a general expectation or readiness to look for and detect the presence of symbolic relations between entities" (DeLoache, 1995, p. 112). Evidence for the connection between MSL and symbol reading comes from a longitudinal study (Nieding et al., 2016), which showed that children's MSL at age 4 years predicts their competence in precursors of reading and writing as well as mathematics—skills that rely heavily on the understanding and manipulation of symbol systems.

However, our conception also encompasses more complex symbol systems such as formal features and early skills of critical evaluation, such as the reality-fiction distinction, as outlined in the following sections.

1.1.1. Understanding formal features of television

Viewing films and related media requires an understanding of the visual production and editing techniques characteristic of such symbol systems. Because film's formal visual features (Rice, Huston, & Wright, 1986) are often used to compress time and space or to emphasize certain information, comprehension of such features is a crucial component of film literacy. This facility has become increasingly important as the pace of editing in modern formats accelerates, even in children's programs—for instance, the editing pace of *Sesame Street* increased from 4 cuts per minute in 1977 to 8 cuts per minute in 2003 (Koolstra, van Zanten, Lucassen, & Ishaak, 2004).

Understanding of editing techniques develops significantly between the ages of 3 and 7 years (Smith, Anderson, & Fischer, 1985). At first, children learn to comprehend the so-called first-order editing rules ("matching the position" and "matching the movement"; d'Ydewalle & Vanderbeeken, 1990), which incur relatively low-level cognitive demands, as they are fairly close to natural perception. In the next step, children come to understand second-order editing rules, related to spatial relations (e.g., movement or viewing direction in dialogue scenes). Finally, rules relating to the continuity of actions (flashback, flash-forward, cross-cutting[1] etc.; third-order editing rules) are understood. These findings are supported by eye movement data for film cuts (Munk, Rey et al., 2012) and by children's re-enactments of film sequences (Munk, Diergarten, Nieding, Ohler, & Schneider, 2012; Smith et al., 1985).

Understanding of formal features is closely linked to children's level of cognitive development. For instance, understanding zoom shots depends on an understanding of physical conservation as described by Piaget (1974), in which preoperational children (usually below the age of 7 years) have difficulty in understanding that a certain quantity will remain the same despite adjustment of the container or of apparent size. This understanding is also required in zoom shots, as an object appears bigger when shown in close-up. Children classified as "nonconservers" (second grade and lower) in a classical Piaget conservation task mistook a candy bar in a television close-up as larger than one in a more distant shot (Acker & Tiemens, 1981). Similarly, an understanding of panning shots (i.e., sideward shifts of scene) seems to be related to visual working memory capacity in pre-school children (Pittorf, Lehmann, & Huckauf, 2014) and their comprehension of spatial relations in dialogue scenes relates to spatial perspective-taking ability (Comuntzis-Page, 2005).

1.1.2. Distinguishing reality and fiction and different program formats

Even 2-year-olds have some understanding that what they see on TV does not usually influence the real world; for instance, they will have more difficulty imitating behavior seen on television as compared to a live demonstration (Hayne, Herbert, & Simcock, 2003). However, the ability to distinguish reliably between reality and fiction does not fully develop until about the age of 11 years. Children's theories about reality and fiction in television develop in parallel with more general fantasy-reality judgments (Mares & Sivakumar, 2014). In making this distinction, children's errors go both ways; young children often believe that fictional events are real, but they can also mistake real events as fictional (Woolley & Ghossainy, 2013). This erroneous skepticism can pose problems when children are required to learn from televised content (Mares & Sivakumar, 2014). In attempting to distinguish between real and fictional content, children refer to different program formats (Wright, Huston, Reitz, & Piemyat, 1994). For instance, 4- to 6-year-old children understand that cartoons are fictional (Downs, 1990), and these can subsequently be distinguished from formats such as *Sesame Street*. Eventually, news can be discerned from children's and adults' shows (Wright et al., 1994).

1.1.3 Computer literacy

As well as television, children now become accustomed to computers and tablets early in life, and these become increasingly important from about the age of three years (Iene Miene Media, 2012, cited in Bus, Takacs, & Kegel, 2015). Touchscreen devices are also popular with children, and their finger-based interface allows very young children to perform simple tasks (Neumann & Neumann, 2014). Speed and accuracy in tapping and dragging improves significantly between 3 and 6 years of age (Vatavu, Cramariuc, & Schipor, 2015), and children's skill in using pointing devices (e.g., the computer mouse) has been shown to improve continuously in terms of speed and accuracy between the ages of 4 and 12 years (Joiner, Messer, Light, & Littleton, 1998).

A longitudinal study by Saçkes, Trundle, and Bell (2011) revealed that gender had a significant influence on computer literacy development, such that boys showed a larger growth in these skills compared to girls. While socioeconomic status and availability of a computer in the home were unrelated to the development of these skills over time, both predicted children's initial computer skills, suggesting that access is relevant for the development of computer skills in early childhood.

2. Learning from media

Across the wide range of computer-assisted learning materials, research has broadly confirmed their effectiveness (Fletcher-Flinn & Gravatt, 1995; Tamim et al., 2011). For instance, one training study confirmed that Head Start children who used educational software over a period of 6 months performed better on their school readiness tests than children following a standard Head Start curriculum (Li, Atkins, & Stanton, 2006). Similar positive effects of computer-based training were reported for precursors of reading (Mioduser, Tur-Kaspa, &

[1] This technique establishes action occurring at the same time in two different locations. The camera cuts away from one action to another, suggesting simultaneity.

Leitner, 2000) and mathematical skills (Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009). Recent research on apps has also found positive outcomes, for instance, in relation to vocabulary learning (Chiong & Shuler, 2010).

Positive effects have also been demonstrated for educational television, as in the benefits of watching *Sesame Street* and similar educational shows confirmed by several studies and in several countries. These benefits extend to cognitive outcomes such as literacy and numeracy, learning about the world, and social development (Linebarger, 2015; Mares & Pan, 2013; Mares et al., 2015; Penuel et al., 2012). There is also evidence that children can acquire long-term domain-specific knowledge by watching films about certain (mostly scientific) topics (e.g., Michel, Roebers, & Schneider, 2007). This line of research has also examined factors influencing the efficiency of learning from media. Although the influence of MSL on learning from media has not yet been studied, research has examined other influencing factors, as will be outlined in the following section.

2.1. Factors influencing learning from media

Based on cognitive load theory (Sweller, 1988) and evidence of children's limited working memory resources (Koppenol-Gonzalez, Bouwmeester, & Vermunt, 2012), Fisch's (2000) capacity model specifies characteristics of both the film and of the learner that influence how effectively children will learn from educational television. According to this model, children's comprehension of content depends on how demanding the program is and how efficiently children allocate their cognitive resources. It is a central proposition that the distance between narrative and educational content should be minimal—that is, the educational content should be closely embedded in the narrative to reduce cognitive load.

Aladé and Nathanson (2016) tested several of the viewer characteristics proposed by Fisch's model. They found support for the influence of prior content knowledge, verbal reasoning and short-term memory on children's learning from educational television. Knowledge of formal features, a further viewer characteristic in Fisch's model, has not yet (to our knowledge) been empirically tested.

With regard to demographic variables, gender does not influence learning from computers (Roblyer, Castine, & King, 1988). In the case of learning from television, gender seems to exert an indirect influence through identification with the main character, according to the main protagonist's sex (Calvert, Strong, Jacobs, & Conger, 2007). Age is also relevant for learning from media, though interestingly in different directions: while younger children (preschool and kindergarten) gain more than older children and adults from computer-based instruction (Fletcher-Flinn & Gravatt, 1995), the opposite is true of learning from television. Older children learn better from television, which can again be explained by younger children's difficulty with the reality-fiction distinction (Mares & Sivakumar, 2014) and their shorter attention span (Krcmar & Fudge Albada, 2000).

Learning from hypermedia environments is a special case of learning from computers. Hypermedia environments include pictures, videos, and text, configured in a web of links and nodes (Schwartz, Andersen, Hong, Howard, & McGee, 2004). This design requires the learner to create a mental map of the system, which in turn demands skills of visual imagination (Tran & Subrahmanyam, 2013). Users also need to be able to remember which routes they have already explored and to plan where they should search next, entailing increased cognitive load. Student characteristics such as higher working memory capacity can compensate for the higher cognitive demands of hypermedia learning (DeStefano & LeFevre, 2007). Metacognitive skills and experience of hypermedia texts have also been identified as factors influencing success in hypermedia learning (Schwartz et al., 2004).

3. Purpose and design of the present research

In the present study, we examined the effects of media sign literacy on children's learning from an educational film and a hypermedia environment. We assumed that children with more developed MSL would gain more from media-based learning tasks. This hypothesis is based on the fact that every medium uses a particular symbol set—for instance, television uses montage, sound effects, and camera parameters; computer software uses icons, interactive controls, sound effects, and animations. To use educational media, the learner must process all these symbols, using the requisite cognitive capacities. For this reason, we assume that previous knowledge of these symbol systems (that is, MSL) renders processing less demanding, freeing more cognitive capacity for processing of educational content. The findings of two studies from our workgroup support the view that MSL is an important predictor of children's processing of film, as children with high MSL scores were found to be better in processing filmic montage techniques (Munk, Diergarten et al., 2012) and in understanding protagonists' emotional states (Diergarten & Nieding, 2015).

To measure MSL, we used a self-designed online test, with tasks involving the various kinds of media commonly used by young children. To analyze comprehension and knowledge acquisition, we also developed two media-based learning tasks with corresponding recognition and inference questions. We did not measure children's previous knowledge of the topics, as this would have had the disadvantage of activating and inducing knowledge via the pre-test (Viteri, Clarebout, & Crauwels, 2014), making it difficult to compare the results to natural media use settings. Due to the lack of baseline scores, we could not establish whether children's scores owed to comprehension of previously known information or to newly acquired knowledge that could actually be described as learning. For this reason, we refer here to both *comprehension* and *knowledge acquisition* in respect of observed knowledge scores.

The first task included a 6-minute film clip about sugar production; the second involved a hypermedia learning interface related to people, animals, plants, and architecture in various countries. Because our participants were not yet able to read, the user interface was implemented using pictures and corresponding audio files. The questionnaire included recognition and inference questions to be answered immediately following completion of each task.

To control for other factors of possible relevance, we also assessed children's intelligence, their media usage behavior (i.e., duration and diversity), and their family's socioeconomic status. Hierarchical regression analyses were performed to assess each factor's impact on comprehension/knowledge acquisition.

4. Method

4.1. Participants

A total of 150 children (70 girls, 80 boys) with a mean age of 5.33 ($SD = 0.55$; range: 4.42 to 6.33) participated in the study. The children were recruited through the daily newspapers and by contacting local daycare centers in the area of Chemnitz and Würzburg, Germany. German was the native language of all participants. Only children whose parents had given their written consent participated in the study.

4.2. Material

4.2.1. Media sign literacy

The individual level of MSL of the participants was assessed by an online test developed by the authors (Nieding et al., 2016). The test measures knowledge of media sign systems of various kinds (e.g., film/TV, computer interfaces, picture books, and comics) in children between the ages of 3 and 6 years. The test comprises ten subscales (nine computer-based and one non-computer-based; see Table 1 for short descriptions and example questions). For further information about this test, the pilot study, and the method of choosing items and subscales, see Nieding et al. (2016).

For the computer-based subscales, the children were given instructions by an animated tutor (a lip-synchronous animated monkey). Participants then had to choose an appropriate answer from several forced-choice alternatives, using a computer mouse. To ensure that all participants could interact properly with the program, each child received brief computer mouse training before the test. Response times were recorded, but these did not influence children's scores, as responses were coded only as *right* or *wrong* for scoring purposes.

The tenth subscale measures children's comprehension of filmic montage with a method introduced by Smith et al. (1985). Participants were asked to reconstruct animated films using Playmobil dolls after watching five film sequences produced by the authors involving different montage techniques, such as flashbacks, point-of-view shots, or simultaneity of action. Pilot studies identified the five selected films as best for confirmation of montage comprehension in children aged between 5 and 8 years (Munk, Diergarten et al., 2012). Following presentation of each sequence, the child was asked to re-enact the film, using all the characters and other material shown in the video. This reconstruction was then rated in terms of montage comprehension.

The main scores of all ten MSL subscales were divided by the number of their items, and a total score was calculated from these quotients. The sum was then divided by ten, yielding a main score ranging from 0 to 1.

4.2.2. Intelligence

Participants' nonverbal intelligence was measured on a shortened version of the Culture Fair intelligence test (Cattell, Weiß, & Osterland, 1997), using the two subscales *Classification* and *Matrices*. The former measures ability to classify figural objects; in each trial, participants were shown five objects and had to identify the odd one out. The time limit for the 12 trials was 5 min.

Table 1
Subscales and examples of the media sign literacy test.

Subscale	Example
1) Ability to differentiate between TV realism and fiction	Real wedding vs. staged wedding: "In which one of these films did the man and the woman really get married?"
2) Ability to differentiate between several filmic genres	Differentiation between fiction, news, and advertisements: "Which one of the three is not an advertisement?"
3) Ability to match a presented voice with its corresponding character in audio books	Voices of dwarf, fairy, bear, wizard etc. "Click on the picture of the character that was speaking."
4) Ability to detect emotions in comic faces	Manga figure with happy, sad or bored facial expression: "Which one of these persons is happy?"
5) Visual portrayal of different characters' perspectives	Landscape scenes from the perspective of animals of different sizes (elephant, tiger, and ant): "Was this photo taken by the tiger, by the elephant, or by the ant?"
6) Ability to understand the narrative continuity of film stories	Anticipating how a story continues by choosing one of three pictures after watching a short film sequence: "Which picture shows how the movie would continue?"
7) Knowledge about the symbolic use of colors in everyday settings	Traffic lights, water taps: "Which one of these traffic lights has the right colors?"
8) Symbolic understanding of maps	Symbols for lakes, mountains, or towns in maps: "Show me the mountain on this map."
9) Knowledge of computer user interfaces	Pictograms such as an X symbolizing the exit function: "Where would you click if you wanted to exit the game?"
10) Comprehension of filmic montage (not computer-based)	Flashback, point-of-view shot, simultaneity of action cut; child is presented with all puppets and material shown in the film and asked "Can you show me what happened in the film?"

The *Matrices* subscale requires participants to recognize rules and patterns. In each of the 12 trials, an incomplete pattern was shown, and the child had to choose one of five pictures that would fit this pattern. Time was limited to 7.5 min.

The total score of the two subscales was divided by 24 (the maximum possible score), resulting in a score ranging from 0 to 1.

4.2.3. Knowledge acquisition from educational film

We used a 6:44 minute clip of the popular German TV program for children between 3 and 13 years, *Die Sendung mit der Maus* (*The Program with the Mouse*). The show typically consists of educational films and cartoons. The films are short documentaries (about 5 to 10 min in length) that explain the production or operation of everyday objects. The film clip used in the present study was a typical example of these educational films, explaining the production of sugar from sugar beet. This film was selected because of its proven suitability for studies of learning from educational TV, as previously confirmed by Michel and colleagues (e.g., Michel et al., 2007).

In the first 30 s of the film, an elderly man who typically introduces the educational segments in this show is seen drinking a cup of coffee and spooning some sugar into it. He briefly describes the different ways of producing sugar, and the film then goes on to show how sugar beets are harvested, transported to the sugar factory, washed, sliced, boiled, and centrifuged. The film concludes by showing different end products such as sugar cubes and rock candy.

After viewing the film, a questionnaire with 18 items was read to participants in a forced-choice format, with three options for each item. The questions were of two types: recognition questions and inference questions. The ten recognition questions related directly to information provided in the film clip (e.g., "What color is a sugar beet?—a) brown; b) green; or c) red"). The eight inference questions referred to facts that had not been explained directly but could be answered by drawing conclusions or from general knowledge (e.g., "Why are there side slits on the cooking pot?—a) because light is needed for cooking sugar; b) so that you can see how far the cooking process has advanced; or c) because it looks better").[2] The two types of question were presented in mixed order. Each correct answer scored 1 point. The total score for each scale was divided by 10 or 8, respectively, and end scores ranged from 0 to 1.

4.2.4. Knowledge acquisition from hypermedia environments

We created a hypermedia environment specifically for the purposes of the present study. Designed as a hierarchically linked hypertext and presented on a computer, it was programmed using *Adobe Flash* and *ActionScript* in combination with *MDM Zinc* authoring software. Navigation involved a computer mouse and buttons with symbols commonly used in computer interfaces (e.g., a house to return to the start page; a hand with forefinger pointing to left or right to navigate back or forward). Because it teaches about people, animals, plants, and buildings in different parts of the world, the environment was called *Discover the World*.

Navigation is possible on four levels. The first level presents the four main categories (people, animals, plants, and buildings/architecture). Clicking on one of these categories leads to the second level, which presents a set of three or four sub-categories (for example, the category *animals* includes *bear*, *whale*, *penguin*, and *kangaroo*). The sub-categories are presented as pictures, with an arrow pointing to the location of each item on a world map (e.g., typical habitats). Choosing a sub-category leads to a third level, which provides general information about the chosen item (e.g., "Kangaroos live in Australia. They carry their babies in a pouch.") and invites the user to click on a button depicting

[2] The film scene and the questions were presented in German, as all the participants were Germans.

a magnifying glass for further information (e.g., “If you want to know how kangaroos move about, click on the magnifying glass”). Clicking this button leads to a fourth level, providing more detailed information (e.g., “If the kangaroo wants to move fast, it jumps with its hind legs and uses the tail for balance. It can jump as fast as a car driving in the city.”). All items are presented using pictures and text, simultaneously accompanied by prerecorded audio files of a female narrator.

Before testing commenced, a five-minute long exploration phase allowed the child to explore the software on their own. Then, participants were presented with eight search tasks to ensure that each child worked through the complete hypermedia environment. For that purpose, they were shown eight screen shots of single pages to search for in the program.

As in the case of the educational film, a questionnaire was read to participants after they had finished exploring. This contained 20 items in a forced-choice format, with three options. Again, the questions consisted of recognition (12 items) and inference questions (8 items). An example of a recognition question would be “How fast can a kangaroo jump?—a) like a car in the city; b) like a tiger on hunt; or c) like a bicycle on the street.” An example of an inference question would be “Why is Neuschwanstein Castle not inhabited by a king?—a) because the castle is very old; b) because the king lives in a different castle; or c) because Germany doesn't have a king.” As explained above, each correct answer scored 1 point, and both scales were divided by their maximum possible total for a final score ranging from 0 to 1.

4.3. Parent questionnaire

4.3.1. Duration and diversity of media usage

Parents were asked to complete a questionnaire relating to their child's media experience. The questionnaire asked about the types of media their child was exposed to in their everyday environment (including television, cinema, computers, books, comics, newspapers, magazines, audio books, and radio) and the duration of their daily media usage. Parents had to indicate at which hours of the day the child usually used one of those media. From these data, we calculated one score for diversity of used media and one for duration of media usage.

4.3.2. Socioeconomic status (SES)

Parents were not asked directly about their SES (e.g., yearly income) because of prior experience that many parents refuse to answer this question. Instead, we asked both parents to state their profession, and SES was then estimated using the Magnitude Prestige Scale (MPS) (Wegener, 1985), a validated measure that is highly correlated with actual SES (Hadjar, 2004). The MPS consists of a list of professions and assigns a prestige score to each, ranging from 20 (lowest ranked profession) to 186.8 (highest), based on representative surveys (Wegener, 1988). In our sample, scores ranged from 32.9 to 186.8 for fathers and from 42.1 to 186.8 for mothers.

4.4. Procedure

Each child was tested individually in two sessions in a quiet room of the laboratory. The parent was allowed to accompany the child and was asked to sit at the rear of the room. During the first session, the parent was asked to fill out the parent questionnaire. In the first session, the child completed the online MSL test and the intelligence test. The average total time for this session was approximately 50 min. Because that is a long time for a young child to sit still and concentrate, we included a break between the two tests and made sure that the child moved around during this time, with an opportunity for free play and a drink and snack.

In the second session, the participant first watched the educational film and answered the questionnaire. After a break like that in the first session, the child was presented with the hypermedia interface *Discover the World*, followed by the relevant questionnaire. The average duration of the second session was approximately 40 min.

5. Results

5.1. Correlations

All skill variables and diversity of media use were highly correlated with age, as might be expected in a study involving small children. For that reason, all other correlations were calculated as partial correlations controlling for participant age. Table 2 presents an overview of these correlations. With the exception of the hypermedia inference scale, all comprehension/knowledge acquisition scales correlated significantly with each other and with intelligence and MSL. Hypermedia inference was correlated only with film recognition. Parents' SES was correlated with recognition scores for both film and hypermedia environment. The two measures of media usage were correlated only with each other and with age (only diversity of media use), but not with any other measure.

5.2. Knowledge acquisition from film and hypermedia

Descriptive statistics showed that participants answered more than half of the questions correctly on each scale: film recognition: $M = .67$ ($SD = .22$); film inference: .59 (.19); hypermedia recognition: .52 (.19); hypermedia inference: .60 (.17). Table 3 gives an overview of the means and standard deviations of all scores.

Because they dealt with different topics, ANCOVAs were calculated separately for film and hypermedia, as a comparison would risk confounding content and medium. The two types of scores (recognition and inference question scores) were entered as within subject factors and age as covariate. For the educational film, an ANCOVA revealed a significant main effect of age on correct answers, $F(1, 148) = 27.82$, $p < .001$, $\eta_p^2 = .16$; the main effect of question type on correct answers was not significant ($F < 1$). Age did not significantly moderate the main effect of question type ($F < 1$). For the hypermedia environment, the ANCOVA revealed a significant main effect of both age, $F(1, 148) = 38.42$, $p < .001$, $\eta_p^2 = .21$, and of question type on correct answers, $F(1, 148) = 9.40$, $p = .003$, $\eta_p^2 = .06$. Age significantly moderated the influence of question type, $F(1, 148) = 7.03$, $p = .009$, $\eta_p^2 = .06$.

To examine the interaction of age and question type for hypermedia scores, we divided the children's data into two groups (younger and older) using a median split. The cut-off point for the median split was 5.25 years, and the mean ages of the two groups were 4.83 and 5.83, respectively. *t*-tests revealed that older children had significantly higher scores for both types of hypermedia questions as compared to younger children: hypermedia recognition: $t(148) = -5.70$, $p < .001$; hypermedia inference: $t(148) = -2.64$, $p = .009$. The difference between hypermedia recognition and hypermedia inference was not significant in the group of older children, $t(74) = -1.24$, $p = .219$, but in the group of younger children, $t(74) = -4.75$, $p < .001$, hypermedia inference scores ($M = .56$, $SD = .17$) exceeded hypermedia recognition scores ($M = .44$, $SD = .16$). Further *t*-tests showed no significant effects of sex, either in any of the recognition and inference scores or in the intelligence and MSL scores.

5.3. Influences on comprehension/knowledge acquisition

A hierarchical regression analysis was calculated to assess whether intelligence or MSL explained more of the variance in comprehension/knowledge acquisition scales. The first block included the age of the participants; in the second block, MSL and intelligence were added as variables for a stepwise regression. The model parameters are indicated in Table 4.

In relation to film recognition, age alone predicted 12% of the variance. Addition of MSL in the second model increased the explained

Table 2
Partial correlations between intelligence, media sign literacy (MSL), the 4 questionnaire scores, socioeconomic status of the parents and duration and variety of media usage. The correlation of age is partialled out of all correlations; correlations with age are shown in the bottom row.

	MSL	I	F-R	F-I	H-R	H-I	SES F	SES M	DuMu	DiMu
Intelligence (I)	.30***									
Film recognition (F-R)	.37***	.37***								
Film inference (F-I)	.29***	.25**	.38***							
Hypermedia recognition (H-R)	.31***	.17*	.43***	.33***						
Hypermedia inference (H-I)	−.09	.03	.23**	.11	.07					
Socioeconomic status father (SES F)	.07	.09	.18*	.02	.24**	.01				
Socioeconomic status mother (SES M)	.06	.07	.23*	.09	.27***	.09	.48***			
Duration of media use (DuMU)	.12	.04	.07	.02	.03	−.04	.00	.02		
Diversity of media usage (DiMU)	.06	.15	.13	.13	.16	.09	.17	.08	.26**	
Age	.33***	.23**	.35***	.33***	.46***	.22**	.08	.00	.08	.31***

* $p < .05$.
** $p < .01$.
*** $p < .001$.

variance to 24%, and addition of intelligence in the third model added another 7%, yielding a total of 31% explained variance. The results for film inference scores were similar; MSL was added as the second variable and intelligence as the third, explaining an additional 7% and 3%, respectively, for a total of 21% explained variance. The age of the participants accounted for 21% of variance in hypermedia recognition scores; MSL added another 8%, for a total of 29%. Intelligence did not significantly add to the model. With regard to hypermedia inference scores, age was the only included factor, explaining 5% of the variance.

In conclusion, it would seem that MSL plays an important role in children's comprehension and knowledge acquisition from film and hypermedia, explaining more of the variance than intelligence. Drawing of inferences from media content was influenced by MSL and intelligence for film but not for the hypermedia environment.

6. Discussion

The main finding of our study is that media sign literacy is an important factor in explaining individual differences in children's ability to comprehend and learn from media. Our interpretation of this finding is that children with high MSL are more proficient in processing and operating the symbol systems used by media—for example, in understanding sound effects and visual features like montage in the educational film or, in case of the hypermedia environment, understanding symbols that guide navigation and the cognitive challenge of navigating through several levels of the hypermedia environment without losing orientation. For this reason, children with high MSL use less cognitive capacity in processing and working with the medium, leaving more remaining capacity for processing the educative message.

This interpretation is generally consistent with Fisch's (2000) cognitive capacity model, which proposes that children's comprehension of educational television depends on their allocation of working memory resources, which in turn depends both on features of the film and on the child's characteristics; among the latter is the child's knowledge of the formal visual, auditory, and sequential features that organize well-formed audiovisual texts. While this part of the model has not yet been empirically tested, our results align with this assumption. However, we extend Fisch's statement by arguing that, beyond knowledge of formal features, other components of MSL are of importance in predicting comprehension of educational television and educational hypermedia.

It is important to emphasize that MSL relates not only to recognition of information explicitly mentioned in the educational film or hypermedia but also to the child's ability to draw further inferences about the educational film's topic. This confirms Ohler's (1994) assumption that media literacy helps to build more profound situation models and replicates our recent finding (Diergarten & Nieding, 2015), that children with high MSL are better able to draw inferences about a protagonist's emotional state in movies and audio books. As the protagonist's emotional state was never mentioned in the stories, participants had to make these inferences by further processing of the story's content. This echoes the findings of the present study, as in both cases, MSL predicted both the processing of explicitly stated information and the ability to go beyond this content by making inferences.

With regard to the questionnaire relating to hypermedia content, MSL predicted the scores for recognition but not for inference. For the latter, age was the only predictor included in the model, and MSL and

Table 3
Percentage of male and female participant; means and standard deviations of age, media sign literacy, intelligence, the 4 questionnaire scores, and socioeconomic status of the parents.

	%	M	SD
Sex			
Male	53.33		
Female	46.67		
Age (years; months)		5.33	0.55
Media sign literacy		.62	.11
Intelligence		.36	.15
Film recognition		.67	.22
Film inference		.59	.19
Hypermedia recognition		.52	.19
Hypermedia inference		.60	.17
Socioeconomic status father		83.39	36.07
Socioeconomic status mother		2.23	33.79

Table 4
Model parameters for hierarchical regressions analyses.

	Variable	B	SE B	β	p	R	R^2	Δ Change in R^2
Film – recognition								
Model 1	Age	0.01	0.00	.35	<.001	.35	.12	
Model 2	Age	0.01	0.00	.23	=.004	.49	.24	.12***
	MSL	0.71	0.15	.37	<.001			
Model 3	Age	0.01	0.00	.19	=.011	.55	.31	.07***
	MSL	0.55	0.15	.29	<.001			
	Intelligence	0.41	0.11	.27	<.001			
Film – inference								
Model 1	Age	0.01	0.00	.33	<.001	.33	.11	
Model 2	Age	0.01	0.00	.23	=.004	.43	.18	.07***
	MSL	0.48	0.13	.29	<.001			
Model 3	Age	0.01	0.00	.21	=.009	.46	.21	.03*
	MSL	0.39	0.14	.23	=.005			
	Intelligence	0.23	0.10	.18	=.029			
Hypermedia – recognition								
Model 1	Age	0.01	0.00	.46	<.001	.46	.21	
Model 2	Age	0.01	0.00	.36	<.001	.54	.29	.08***
	MSL	0.50	0.12	.30	<.001			
Hypermedia - inference								
Model 1	Age	0.01	0.00	.22	<.01	.22	.05	

* $p < .05$.
*** $p < .001$.

intelligence did not explain additional variance. One possible explanation of this result is that participants may rely heavily on previous knowledge in answering the inference questions. This hypothesis is supported by our finding that inference scores were higher than recognition scores in the hypermedia questionnaire. It is worth noting that we did not find this pattern in the film questionnaire, where recognition and inference questions did not differ significantly. We assume that previous knowledge was less important in the film questionnaire, as the film focused on a very specific topic (sugar production), of which participants were unlikely to have detailed knowledge. By comparison, the hypermedia questions touched on information that is more in line with children's usual interests, such as animals. This remains an assumption, however, as we did not assess the children's previous knowledge. There may also be media-specific reasons that account for these differences between recognition, inference and the use of previous knowledge. However, given that the two media presented different topics, we must refrain from interpretations concerning modality effects.

Controlling for the age of the participants, partial correlations revealed a correlation between intelligence and MSL, replicating another of our work group's findings (Nieding et al., 2016). Our interpretation is based on the fact that MSL and intelligence share a mutual source, as both require the ability to interpret and work with symbols. In particular, nonverbal intelligence tests such as those employed in our studies require operations as classification of figurative objects and recognition of patterns within these objects. Although the intelligence and MSL tests drew on different symbol sets, the underlying skills—that is, the manipulation of internal representations and cognitive organization of the interplay of internal and external representations—are familiar and therefore explain shared variance.

Family socioeconomic status (SES) was correlated with both types of recognition scale but not with either the inference question scales or any other scale. A simple explanation of the correlations between SES and recognition might be that children from high-SES families had greater prior knowledge of the taught topics. As we did not assess children's baseline knowledge, this possibility cannot be excluded. However, given that SES was correlated only with recognition scores but not with inference scores, we think it unlikely that previous knowledge is the essential moderating factor. As mentioned above, we assume that inferences depend more heavily on previous knowledge than recognition, as the inferences were not explicitly mentioned in the learning material (e.g., the knowledge that Germany does not have a king in answering the question "Why does no king live in Neuschwanstein Castle?"). As only the recognition questions were correlated with SES, another explanation must be sought for this correlation. An alternative hypothesis follows from the finding that high-SES parents are known to regulate their children's media usage more extensively by choosing appropriate content, co-viewing, and discussing the content, as compared to lower-SES parents (Natsiopoulou & Melissa-Halikiopoulou, 2009). For that reason, children from high-SES families may be more accustomed to educational programs and would therefore be more likely to expect learning content than children who mainly consume entertainment media. Parental co-viewing is also known to have beneficial effects on children (Robb & Lauricella, 2015), which may also be reflected in the identified correlation.

Duration and diversity of media usage were correlated with each other but not with the comprehension/knowledge acquisition scales. Although this result aligns with Aladé's (2013) finding that there is no connection between media use and knowledge acquisition from educational TV, one should keep in mind that our media use scores are based on parent estimates and might therefore be distorted by both estimation errors and social desirability effects (Ennemoser, 2008).

6.1 Limitations and future directions

In future research one might assess previous knowledge before children are presented with the educational media. That would help distinguishing between comprehension of previously known information and newly acquired knowledge. However, one has to bear in mind that such an assessment introduces other problems, as a pre-test would activate children's knowledge of the subject and other learning processes beyond those assumed to occur in natural media-based learning settings (Viteri et al., 2014).

The hypermedia environment may also diverge from children's natural experiences with educational software and apps. While use of our program was not unlike knowledge acquisition through Internet research, this activity is probably quite rare among younger children, and educational software or apps for children of that age usually require less navigation. However, we believe that while those programs differ greatly in terms of handling, learning processes should be similar once the program is opened.

Another shortcoming of the present study is that the four questionnaires used to obtain recognition and inference scores for each medium all contained different questions, resulting in a confounding of question difficulty, educational content, and medium. Future research should employ a between-subject design, presenting the same content in filmic and hypermedia environments, and using the same questionnaire to assess knowledge acquisition and inferences to properly support claims about which medium is more effective for learning. To address questions of causality, this design might usefully be incorporated in a training study, comparing children who have received lessons in MSL with those who have not. Additionally, while the present study focused on MSL's influence as a sub-set of media literacy skills that are relevant in early childhood, future research might assess the influence of media literacy in a wider sense, including subscales to measure explicit knowledge about media and critical evaluation.

6.2. Conclusion

Despite its limitations, the present study contributes to the literature on children's learning from electronic media. One unique element of the study is that it examines both children's recognition and their ability to infer additional information. It also adds media sign literacy to the list of salient children's characteristics, which has not been assessed in prior studies. The construct of MSL as an important aspect in children's comprehension of and learning from media was also supported, underlining the importance of media sign literacy in early education. While media literacy is part of standard school curricula in many countries (Andersen, Duncan, & Pungente, 2004; Buckingham, 1998), the results of this study suggest that teaching of media (sign) literacy should start even earlier, in preschool and kindergarten years. As outlined in the theoretical discussion above, elementary school children still struggle to understand certain aspects of television, many of which are closely linked to developmental immaturities. Teachers should be aware of the difficulties children face when learning from media—as for instance in their possible skepticism about the reality of the presented information (Woolley & Ghossainy, 2013)—and should prepare their students accordingly for media learning sessions. Beyond teaching application-specific aspects of media literacy, such as use of a computer mouse or the difference between educational and entertainment media, we support the idea that the fundamental ability to read media symbol systems—that is, MSL—should form an essential part of early media education. In a previous longitudinal study, we found that MSL among 4-year-olds was a significant predictor for precursors of reading and mathematical skills two years later (Nieding et al., 2016), lending additional support to our claim that MSL is an important topic for early education.

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