Disentangling the effects of video pace and story realism on children's attention and response inhibition

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Abstract

This study examined the influence of the realism (realistic vs. unrealistic) and pace (slow vs. fast), in a video of an actor reading a story, on 4-year-old children's attention and response inhibition. After establishing baseline cognitive performance, 187 children watched novel videos that manipulated realism and pace, while keeping other programme features constant. Irrespective of the pace, watching the videos which presented unrealistic stories improved children's response inhibition. For attention, there was an interaction between pace and realism. Exposure to the fast-paced video resulted in faster responding, but only when the story was realistic. Together the results suggest that a story's realism, rather than the video's pace, affects the inhibitory component of children's executive function; whereas both pace and realism interact to affect attention. We propose that certain types of feature, embedded in a video, can provide a buffer against the negative effects of exposure to fast pace.

Keywords: children; attention; response inhibition; editing pace; television; video, pretence

Introduction

The role of screen-based media, particularly television, in children's cognitive development has been studied for more than 40 years (see Kostyrka-Allchorne, Cooper, & Simpson, 2017, for a review). Much early experimental research focused on the effects of television on task perseverance and sustained attention. These studies used both indirect measures of performance, such as free-play (Anderson, Levin, & Lorch, 1977; Geist & Gibson, 2000), and formal laboratory tests (Anderson et al., 1977; Bellieni et al., 2010; Cooper, Uller, Pettifer, & Stolc, 2009). More recently, the focus has widened to include the construct of executive function (Lillard, Drell, Richey, Boguszewski, & Smith, 2015; Lillard & Peterson, 2011). Executive function encompasses a set of skills that underpin the planned behaviour required to achieve goals, such as, for example, working memory and inhibitory control (see Diamond, 2013, for a review).

Deficits in executive function may result in attention problems (challenging behaviours that include hyperactivity, impulsivity and distractibility), and in more extreme cases are associated with the development of attention deficit hyperactivity disorder (ADHD; for a meta-analysis see Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Although typical and atypical attention development is influenced by genetics (Fan, Wu, Fossella, & Posner, 2001; Friedman et al., 2008; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005), there are also characteristics of a child's environment that may contribute to attentional outcomes later in life (Banerjee, Middleton, & Faraone, 2007; Froehlich et al., 2011; Nigg, Nikolas, & Burt, 2010). Television viewing in childhood has been proposed as one such important environmental influence on the development of attention (Christakis, 2009; Nikkelen, Valkenburg, Huizinga, & Bushman, 2014).

A cognitive-affective analysis, proposed by Singer (1980), set out to explain why television might disrupt the development of attention and cognition. The key proposal of this theory is that children are *passive recipients* of television content, so their attention to the screen is maintained through perceptually salient audio-visual features such as fast pace (generally operationalized as the frequency of camera editing actions and the rate of scene/character changes - for a discussion see McCollum & Bryant, 2003). These intense audio-visual features capture children's attention through repeated orienting responses to on-screen change. Orienting responses may *initiate* attention to change, prepare for stimulus processing (Sokolov, 1990), and raise alertness (Ruff & Rothbart, 1996). However, Singer (1980) argued that constant novelty and on-screen changes, used in children's television, not only drew but also *maintained* their, otherwise distractible, attention. In consequence, extended exposure to fast-paced television may lead to a reliance on the environment to maintain attention, and so cause distractibility during other everyday tasks.

At the same time, the constant flow of new information delivered by fast-paced television interferes with the cognitive activity required to process it. It also leaves less scope to reflect on the content viewed (Singer, 1980; Singer & Singer, 1983). Young children, in particular, may struggle to process rapidly delivered content, because of their immature cognitive skills. In turn, this may promote the development of bottom-up processing biases that favour automatic responses over reflection. In contrast, by providing the viewer with more time to process the content, slow-paced television reduces the burden on cognitive resources, which in turn, facilitates more reflective processing.

In partial support of Singer's theory, correlational studies have identified television as a risk factor for the development of problems in attention (Cheng, Maeda, Yoichi, Yamagata, & Tomiwa, 2010; Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Martin, Razza, & Brooks-Gunn, 2012; Özmert, Toyran, & Yurdakök, 2002) and executive function (Barr, Lauricella, Zack, & Calvert, 2010; Nathanson, Alade, Sharp, Rasmussen, & Christy, 2014). Importantly, these studies have shown a negative association between cognition and both the amount and inappropriateness (e.g., adult-directed) of television watched. This has alerted clinicians and researchers to the potential detrimental effects of television viewing. However, these correlational data are insufficient to explain causal links between television, attention and cognitive dysfunction (Beyens, Valkenburg, & Piotrowski, 2018; Kostyrka-Allchorne et al., 2017).

In contrast to Singer's (1980) proposition, Anderson and Lorch (1983) proposed that children are *active viewers*, and their visual attention to television depends on understanding its content. Thus, the key premise of this theory is that the act of viewing is cognitively engaging, and television's potential to hold attention depends on the viewer's ability to process and understand what is presented on the screen (Anderson & Hanson, 2010; Anderson & Lorch, 1983; Anderson & Pempek, 2005).

These two proposals are not mutually exclusive. Huston and Wright (1983) suggested that audio-visual features were instrumental in conveying narrative meaning (e.g., shifts in time and location). In this way, they make the processing of the content more efficient, which enhances understanding of the events unfolding on the screen. Huston and Wright (1983) suggested that moderate use of audio-visual features is optimal for enhancing this understanding. In contrast, fast pace (which is typical of many entertainment shows) may disrupt the processing of televised content, and ultimately lead to deficits in attention and related functions (Christakis et al., 2004; Lillard & Peterson, 2011).

The hypothesis that a fast pace is detrimental to children's cognition has been tested in several experimental studies with mixed results (Anderson et al., 1977; Cooper et al., 2009; Geist & Gibson, 2000; Kostyrka-Allchorne, Cooper, Gossmann, Barber, & Simpson, 2017; Lillard et al., 2015; Lillard & Peterson, 2011). Two studies provided evidence for negative consequences when watching fast-paced programmes (Geist & Gibson, 2000; Lillard & Peterson, 2011). Geist and Gibson (2000) investigated the effect of a fast-paced entertainment cartoon on 4- and 5-year-olds' play. Children who watched this programme were more unsettled, evidenced by more shifts between play activities, than a control group. Lillard and Peterson (2011) tested executive function. After watching a fast-paced cartoon, performance on a range of executive tasks was significantly worse than a control group. While these findings suggest pace has negative effects on children's performance, they confounded pace with programme content (slow-paced educational vs. fast-paced entertainment), target-age (i.e., a slow-paced programme aimed at preschoolers, vs. a fast-paced programme aimed at older children), and programme realism (e.g., slow-paced reality vs. fast-paced fantasy).

Lillard et al. (2015) subsequently aimed to address the confound between pace and realism using several programmes that varied in these features. They proposed that not only fast pace, but also processing unrealistic events and characters which defy the laws of nature, weakens subsequent executive function in the short-term. The analysis revealed an effect of realism, but not pace. Consistent with Singer's (1980) theory, Lillard and colleagues proposed that watching unrealistic television, which contained many elements of surprise, increased orienting responses, and activated bottom-up processing, which persisted in subsequent tasks. Additionally, they suggested that beyond the attention-dependent, initial stage of information processing, comprehension of unrealistic features might require extensive involvement of executive processes. In consequence, these resources might become depleted. In the long-term, repeated exposure to unrealistic features could impair the development of executive function. However, other possible confounds in the content (e.g., entertainment and education) and features (e.g., target age) of the programmes used in the study remained.

Although it is possible to investigate the effects of pace, while controlling other programme features, such research is rare. In an early study, Anderson et al. (1977) selected most-rapidly and most-slowly paced sections of *Sesame Street* episodes to create the experimental videos. A forty-minute exposure did not affect 4-year-olds' perseverance, impulsivity or level of activity during free-play. Although by using the same programme to create the experimental videos, these authors reduced potential confounds, the possibility that some differences remained between the fast- and slow-paced stimuli cannot be ruled out.

In an attempt to further improve experimental control, Cooper et al. (2009) examined the effect of pace on 4- to 6-year-olds' attention (rather than executive function) using non-commercially produced experimental videos with *identical* narratives. A single video of a narrator reading a children's story was edited to create slow- and fast-paced versions. In contrast to other findings (Geist & Gibson, 2000; Lillard & Peterson, 2011), this study showed some benefits of a fast pace, such as, greater accuracy on an attentional task (Attention Network Task; Fan, McCandliss, Sommer, Raz, & Posner, 2002). Using the same approach, Kostyrka-Allchorne, Cooper, Gossmann, et al. (2017) investigated the effects of pace on preschoolers' unstructured play. Consistent with earlier findings (Geist & Gibson, 2000; Lillard & Peterson, 2011), children in the fast-paced group shifted attention between toys more than the slow-paced control. Thus, whether the effect of pace is detrimental or beneficial to the viewing child may depend on the subsequent task being undertaken.

The present study

The literature delivers conflicting findings regarding the effects of pace on children's cognition. Moreover, the recent suggestion that seeing unrealistic events in videos impairs children's executive function (Lillard et al., 2015) implies that it may be *realism* rather than *pace* that affects cognition. However, considering the possibility that other features may have affected Lillard and colleagues' (2015) findings, uncertainty also remains about the effects of realism. The aim of the current study was to assess the immediate effects of both pace and realism on the attention and executive function of 4-year-olds using specially produced videos matched for other audio-visual features. We measured response inhibition, which involves the suppression of behaviour in the absence of high attentional demands, as it is argued to be the core component of executive function in young children (Diamond, 2013) and adults (Miyake & Friedman, 2012).

In order to test children's response inhibition and attention, the experiment used the day-night task (measuring response inhibition - Gerstadt, Hong, & Diamond, 1994) and a computerised, continuous performance test based on The Test of Variables of Attention (measuring both attention and response inhibition - Greenberg & Waldmant, 1993), respectively. To establish baseline performance, the day-night task was also administered in a pre-video assessment. We chose this task as it has high inhibitory demands, is quick to administer, and offers a relatively pure measure of response inhibition (Simpson & Riggs, 2005; Simpson et al., 2012).

The continuous performance test (CPT) required children to maintain attention and respond to stimuli presented on a computer screen at different locations. Three CPT parameters (omission errors, response times and response time variability) are proposed to measure attention (Edwards et al., 2007; Greenberg & Waldmant, 1993). The fourth parameter - commission errors (i.e., responses on no-go trials) - measures response inhibition (Greenberg & Waldmant, 1993). Finally, to account for differences in performance on continuous performance tests between boys and girls reported in attention literature (Brocki & Bohlin, 2004; Conners, Epstein, Angold, & Klaric, 2003; Greenberg & Waldmant, 1993; Pascualvaca et al., 1997), gender was entered as a covariate in all analyses. Considering the young age of the participants and the monotonous nature of the CPT, this task was administered only once, in the post-video assessment.

We proposed three non-exclusive hypotheses that could reconcile the inconsistencies from the previous literature. Taking into account the evidence suggesting that attention and response inhibition have different developmental trajectories and are dissociable from early childhood (Klenberg, Korkman, & Lahti-Nuuttila, 2001), we predicted that the effects of the experimental manipulation would differ depending on these measured variables.

The first hypothesis focused on the effects of pace on attention and proposed that, consistent with the passive viewer theory of attention to television (Singer, 1980), fast pace elicits an orienting response leading to alertness and preparedness for quick action in the short-term. Thus, it was predicted that children, who watched the fast-paced video, would respond more quickly and make fewer omission errors in the CPT.

Unlike attentional orienting, which is driven by the appearance of a salient stimulus (Sokolov, 1963, 1990), response inhibition is most involved in tasks when it is impossible to rely on automatic processes. Watching slow-paced videos may facilitate more thoughtful cognitive processing, which could carry over to the subsequent tasks. Thus, our second hypothesis predicted that children who watched the slow-paced video would make fewer commission errors on the CPT and perform better on a day-night task. The final hypothesis focused on the effects of realism and proposed that, consistent with Lillard and colleagues (2015), exposure to the unrealistic story read in the videos would reduce children's response inhibition. Thus, it was predicted that children exposed to such unrealistic stimuli would perform worse on our inhibitory performance measures.

Method

Participants

One hundred and eighty-seven children took part (93 girls) ranging in age from 42 to 62 months (M=55 months, SD=5 months). Participants were recruited from an opportunity sample attending pre-schools and primary schools located in a semi-rural county of England, UK. The participants were predominantly White. English Indices of Deprivation 2015 were used as an approximate measure of the participants' socio-economic status (http://dclgapps.communities.gov.uk/imd/idmap.html). Based on the postcodes of participating schools and preschools, children came from areas of diverse socio-economic status, ranging from being in the 50% most deprived to 10% least deprived areas. The experiment was approved by the University of Essex Ethics Committee. Before the study began, the experimenter provided children's parents with information about the project and the experimental procedure and obtained individual consent.

Design

The experiment adopted a between-participant design. Children were quasi-randomly assigned to one of the four experimental conditions: realistic fast (n=46), realistic slow (n=47), unrealistic fast (n=48), unrealistic slow (n=46). For the day-night task, the independent variables were realism (realistic, unrealistic) and pace (fast, slow). Pre-video day-night task score and age were entered as covariates. The dependent variable was the proportion of correct responses on the post-video assessment. Similarly, for the CPT, the independent variables were story realism (realistic, unrealistic) and video pace (fast, slow) and the dependent variables were correct reaction time latency, correct reaction time variability, proportion of omission errors and proportion of commission errors. Furthermore, gender and age were used as covariates.

Apparatus and materials

A 13-inch Apple laptop computer running QuickTime video player was used to present the video stimuli. Audio playback was delivered via Sony speakers. The same machine was used to run the CPT programmed in SuperLab5. Additionally, a Dell Latitude laptop computer and a Nexus-10 (with finger sensor) running BioTrace + software were used to record participants' heart rate and heart rate variability (reported elsewhere).

Videos

By default, all storytelling involves a degree of unrealism. Thus, when selecting the stories, we opted for books that contained a minimal and a maximal amount of fantasy. During initial selection, we considered whether any of the following was present in the story: (1) unreal characters (i.e., characters that do not exist); (2) impossible attributes (i.e., attributes that are physically impossible); and (3) unreal transformations (i.e., transformations that are physically impossible).

Considering these features, two popular children stories were selected: *Charlie and Lola* (realistic content; Child, 2006) and *Room on the Broom* (unrealistic content; Donaldson & Scheffler, 2002). The *Charlie and Lola* book series describes the adventures of a little girl and her older brother. In the selected story, "But Excuse Me That Is My Book", Charlie, Lola and their friend Lotta visit a library to find Lola's favourite book. Although there was a single reference to unrealistic characters in the text: "Books about castles, dragons and volcanoes, monsters and pixies, we judged the text as free of other unrealistic features. In contrast, *Room on the Broom* tells a story about the adventures of a friendly witch and her cat. This book contains a multitude of unrealistic features, such as, a witch, talking animals, violations of gravity.

To produce the experimental videos, a male narrator was filmed reading each story in a room decorated with two large children's toys (a rabbit and a fish) and the same unedited raw footage and audio track were used to create two versions of each video (fast- and slow-paced). The narrator was filmed with three different cameras (narrator front head view, narrator front full view and narrator side view). The recorded material was subsequently edited together with narrative-relevant cartoon images to produce either a slow- or a fast-paced video. Although such relatively short, non-animated story-telling videos represent a modest proportion of children's programming, they are not entirely unfamiliar to young UK viewers (e.g., *CBeebies*

Bedtime Stories - a popular UK programme, which combines footage of a celebrity reading a children's story with illustrations from the book).

In this study, an editing action was specified as a change from the narrator view to a still cartoon image that covered between 50-100% of the screen, or a change between the two different narrator views (e.g., from a head view to a full view – Figure 2). In addition to the editing actions, small size cartoon images and words (covering less than 50 per cent of the screen) were occasionally inserted into each video to make them visually more appealing (Figure 2c).

The editing pace of all experimental videos was similar to that present in typical children's programmes available on British terrestrial TV channels (Table 1). Both versions of *Charlie and Lola* had duration of 6m 15s. For *Charlie and Lola*, the fast-paced video contained on average 16.8 editing actions per minute (32 images and 10 words/sentences), whereas a slow-paced video contained 6.5 editing actions per minute (2 images and one sentence). *Room on the Broom* videos had duration of 5m 8s. The average number of editing actions per minute was 18.8 for the fast-paced version (39 images and 14 words/sentences), and 7.0 for the slow-paced video (2 images and one sentence).

Table 1. Number of camera cuts in the randomly selected 5-minute segments of typical children's shows available in January 2015 on British terrestrial television.

Programme title	Average cuts per minute
Pokemon	16.6
Bear Behaving Badly	14.4
Dragon Riders of the Berk	13.2
Om Nom Stories	9.6
Old Jack's Boat	8.8
Sooty	7.6

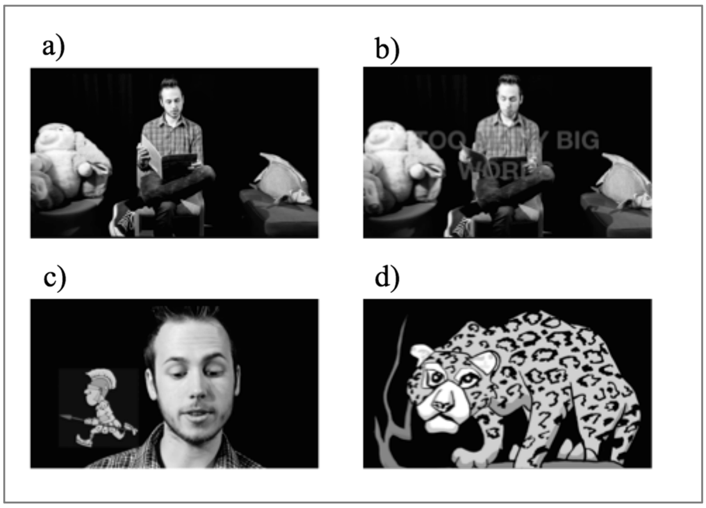

Figure 2. Screen views from *Charlie and Lola*: (a) narrator full view, (b) narrator full view – inserted words, (c) narrator head view – inserted small-size image, (d) cartoon image.

Finally, both fast- and slow-edit versions of the videos were rated for the presence of the unrealistic features by two raters blind to the experimental hypotheses. Their qualitative ratings (shown in Table 2) indicated that the stories read in the videos were clearly distinguishable in terms of realistic and unrealistic content.

Table 2. The description of unrealistic features provided by both raters (R1 and R2) present in the experimental videos. All features listed by the raters in *Charlie and Lola* appear only once in the story. In contrast, many of the features listed for *Room on the Broom* appear multiple times in the story.

Feature	**R1: Charlie and Lola**	**R2: Charlie and Lola**	**R1: Room on the Broom**	**R2: Room on the Broom**
Unreal characters	Dragons	Dragons	Witch Dragon Beast	Witch Dragon Monster
Impossible attributes		Books hiding Cherry blossom rain	Flying broomstick Speaking animals	Flying broomstick Speaking animals Speaking dragon
Unreal transformations			Transforming objects into a broom	Transforming objects into a broom.
Other unreal features			Magic spell Breathing out fire	Magic spell

Day-night task

The materials consisted of two laminated cards showing grey-scale pictures of the sun and moon used to explain the procedure, and an A4 size flip-book, containing 10 individual grey-scale pictures of the sun (S) and 10 individual pictures of the moon (M) presented in the following order: SMSMSMSMSSMMSMSSMMSM.

CPT

The stimuli were shown on a computer screen and consisted of a white 100m x 100mm square presented on a black background, and a picture of the yellow smiley face, with a diameter of 21mm, that appeared centrally on the white square in either “up” (target) or “down” (non-target) position. Two laminated cards showing the smiley face in target and non-target position were used to explain the rules of the task.

Procedure

The experiment took place in a quiet room that was separate from the main classroom area. Children were tested individually, and each session lasted approximately 15 minutes. Both the experimenter and child were sat next to each other at a low table. On the table, there were two laptop computers, a flipbook and the laminated instruction cards. Each child was positioned in front of an Apple laptop, to the right of the experimenter. At the beginning of the session, the experimenter briefly explained the plan for the testing session to each participant. Following this brief set-up, a day-night task was introduced to the children, and the experimenter explained the rules of a “silly game” using two laminated cards. The children were instructed to say “moon” when shown a picture of the sun and “sun” when shown a picture of the moon. The task began with four practice trials (with feedback), followed by 16 experimental trials (no feedback). Once a child finished the day-night task, the experimenter explained that a child would now watch a “film” on the laptop computer. To encourage attention to the videos, the experimenter reminded that “Now is time to watch a film”, if a child stopped looking at the screen.

Following viewing the video, the child completed the CPT. The experimenter explained the rules of the “smiley face game” using two laminated cards. The children were instructed to press the space bar on the laptop keyboard every time a smiley face appeared in a target position and to withhold a press when the smiley face appeared in a non-target position on the screen. Participants were then asked to repeat the instructions and show the experimenter which key to press. The experimenter explained that the stimulus would be visible only very briefly and that it was important to keep looking at the screen all time. The task had 126 trials organised into two consecutive blocks. The targets were presented randomly; in the vigilance block there were 14 targets and in the impulsivity block there were 49. Each stimulus was presented on the screen for 100 ms and the length of the interval between stimulus presentations was 2000 ms.

There was no break between the two task blocks and the order of block presentation was fully counterbalanced. The experimenter reminded the child to pay attention to the screen during the game, but no further instructions or attempts to encourage children's attention to the task where provided while the child was completing the task.

Upon completion of the CPT, children took part in the second day-night test. The experimenter briefly reminded each child the rules, and the testing followed with four practice trials and 16 experimental trials. At the end of the session each child received a small reward for taking part.

Results

On average, children completed 124 trials on the CPT. Anticipatory responses made within 100 milliseconds of stimulus presentation were excluded from the data analyses (Conners & Staff, 2000), which removed 3% of the target trials. Four mean scores were calculated for each child: correct response time, correct response time variability, omission errors and commission errors (Table 3). For the day-night task, pre- and post-video accuracy was calculated for each participant (Table 3). There was no significant difference in the pre-video day-night task performance between the four conditions (all p-values >.05).

Table 3. Children's mean (SD) correct performance on the pre- and post-video day-night task and the continuous performance task (CPT).

Variable	**Experimental group**			
	Realistic fast	Realistic slow	Unrealistic fast	Unrealistic slow
Pre-video day-night task (%)	61 (27)	67 (23)	68(19)	69 (21)
Post-video day-night task (%)	70 (19)	71 (21)	76 (18)	76 (19)
CPT reaction time latency (ms)	862 (163)	960 (168)	951 (190)	886 (181)
CPT reaction time variability (ms)	346 (94)	357 (100)	333 (87)	356 (109)
CPT omission errors (%)	26 (13)	32 (18)	28 (16)	27 (17)
CPT commission errors (%)	39 (29)	35 (28)	32 (29)	39 (29)

Correlations between the indices of performance

Pearson correlations and partial correlations controlling for children's age were performed between the five indices of performance measured after video exposure (Table 4). The day-night task accuracy, which measured response inhibition, was negatively correlated with both the proportion of the CPT commission errors (also measuring response inhibition) and with CPT reaction time variability (measuring inattention). However, after controlling for age, only the relationship between day-night task and response time variability remained significant. Further, we performed the analysis between the four CPT indices that measured attention. The reaction time latency positively correlated with response time variability and the proportion of omission errors and negatively with commission errors. These correlations remained significant after controlling for age. Finally, reaction time variability was positively correlated with both omission and commission errors and these correlations remained significant when age was controlled for.

Table 4. Pearson correlations and partial correlations controlling for age (shaded area) between indices of performance measured after video exposure.

	1	**2**	**3**	**4**	**5**
1. Day-night accuracy	1	0.117	-.175*	-.071	-.112
2. CPT reaction time latency	0.108	1	.170*	.266**	-.375**
3. CPT reaction time variability	-.220**	.155*	1	.340**	.425**
4. CPT omission errors	-.104	.261**	.414**	1	-.092
5. CPT commission errors	-.149*	-.356**	.435**	-.051	1

* p<.05, **p<.001; CPT=continuous performance task

Day-night task

The post-video data were analysed in an analysis of covariance (ANCOVA), with realism (realistic, unrealistic), pace (fast, slow) as between-participant variables and age and pre-video day-night accuracy as covariates. The results showed a significant main effect of realism, F(1,170) = 4.34, p=.039, η_p^2=.025, but no main effect of pace (p=.976), and no Realism x Pace interaction (p=.808). Children who were exposed to unrealistic features in the story had higher day-night accuracy scores than children who were not (M=76%, SD=19% and M=70%, SD=20%, respectively). Thus, watching a video of an actor reading a story with unrealistic features resulted in more controlled responding. As would be expected, there was also a significant main effect of pre-video day-night task accuracy on the post-video performance, F(1,170) = 40.33, p<.001, η_p^2=.192.

The CPT

The CPT performance data were analysed with a multivariate analysis of covariance MANCOVA, with realism (realistic, unrealistic), pace (fast, slow) as the between-participant variables and age and gender as the covariates. The results showed no main effects for pace (p= .775) or realism (p= .929). There was however a significant Realism x Pace interaction, Wilks's Lambda, F(4,175) = 3.77, p=.006, η_p^2=.075. Further univariate testing revealed that this interaction was only significant for the reaction time latency, F(1, 178) = 12.24, p=001, η_p^2=.064 (Figure 3). Follow-up independent samples t-tests (Bonferroni-corrected) showed that the effect of pace was only present in the group that were exposed to the realistic story . The children who watched a fast-paced version of the realistic story responded faster than the children who watched a slow-paced version, t(91)=-2.86, p=.020, 95%CI: 29.98 to 165.88ms. Thus, watching a fast-paced video resulted in faster responding, but only when the story read in the video was realistic.

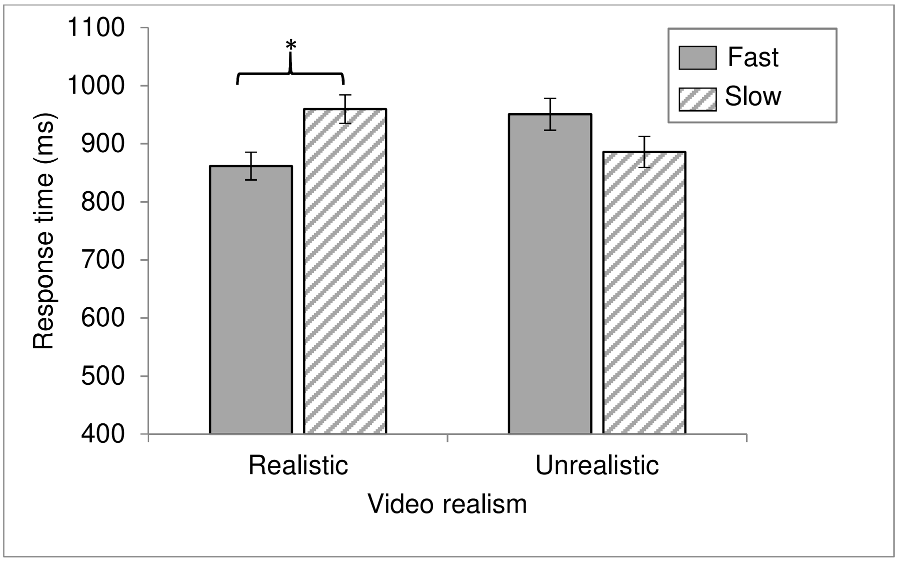

Figure 3. Mean CPT reaction time latencies in the fast- and the slow-paced condition at both levels of realism. Error bars represent SEMs. Asterisk denotes a significant difference ($p < .05$).

There were no further significant main or interactive effects of realism or pace on the reaction time variable. However, MANCOVA also showed a main effect of age, Wilks's Lambda, $F(4,175)= 6.23$, $p<.001$, $\eta_p^2=.125$ and a main effect of gender, Wilks's Lambda, $F(4,175)= 8.97$, $p<.001$, $\eta_p^2=.170$.

Further univariate testing showed that age affected reaction time variability, $F(1,178) = 22.27$, $p<.001$, $\eta_p^2=.111$, omission errors, $F(1,178)=8.16$, $p=.005$, $\eta_p^2=.044$ and commission errors, $F(1,178) = 5.80$, $p=.017$, $\eta_p^2=.032$. Older children's responding was characterised by lower variability and fewer errors. Univariate analysis of gender effects, showed that gender affected reaction time variability, $F(1,178)=9.99$, $p=.002$, $\eta_p^2=.053$, reaction time latency, $F(1,178)=10.86$, $p=.001$, $\eta_p^2=.058$ and commission errors $F(1,178) = 24.91$, $p<.001$, $\eta_p^2=.123$. The girls' response times were less variable than those of the boys (M=324, SD=91 and M= 371, SD = 99), and were slower (M=955, SD=183 and M=876, SD = 168). Finally, the proportion of commission errors made by the girls was lower compared with the boys (M=26, SD=25 and M=46, SD=28, respectively).

Discussion

The key aim of this study was to investigate the effects of video pace and story realism on children's attention and response inhibition. Together, the results of the two tasks suggest that watching a short experimental video of an actor reading a story can affect children's cognition, although support for our three hypotheses was mixed. Considering our first hypothesis, children who watched a fast-paced video featuring a realistic story had faster reaction times on the CPT than their peers who watched the slow-paced version. This finding was consistent with our prediction about the effects of fast pace on attentional performance. However, this effect did not extend to a group that watched the video of an actor reading an unrealistic story. It appears that fast pace affected attentional processing, but only in the presence of realistic features.

Turning to the second hypothesis, we did *not* observe that slow pace improved children's immediate response inhibition. However, inhibition *was* affected by the story's realism. Contrary to our third hypothesis, which predicted poorer inhibition following exposure to unrealism, the children who had watched the video of an actor reading an unrealistic story performed better on the day-night task than their peers who had watched a video featuring realism. These data suggest that exposure to unrealistic features can be beneficial for children's response inhibition, and contrast with the findings of Lillard et al. (2015), who showed that children's executive function (of which response inhibition is a component) was lower following exposure to unrealistic programmes. However, it must be noted, inhibitory performance measured in the CPT (i.e., commission errors) remained unaffected by exposure to the video.

In addition to the findings related to video pace and story realism, correlations between CPT measures of reaction time, variability, omission and commission errors suggest that these indices of performance reflect a common construct, that is, attention. Conversely, after controlling for age, there was no association between our two measures of response inhibition (CPT commission errors and day-night accuracy). Finally, this study found evidence for gender differences in responding on the CPT with boys making quicker, more variable responses with more commission errors. This finding is consistent with the literature and demonstrates gender-related differences in attention during early childhood (e.g., Brocki & Bohlin, 2004; Conners et al., 2003; Greenberg & Waldmant, 1993; Pascualvaca et al., 1997). In the discussion that follows, we consider why video pace and realism affect attentional and inhibitory performance.

The effects of pace and realism on inhibitory control

In this study, the inhibitory component of executive function was measured with the accuracy of responding on the day-night task and with the number of commission errors made in the CPT (i.e., erroneous responses on no-go trials). The findings showed that watching videos featuring an unrealistic story affected children's performance on the day-night task, but not the CPT. This apparent discrepancy may have occurred because, compared with the CPT, the day-night task is a relatively pure measure of response inhibition with particularly high inhibitory demands (Simpson & Riggs, 2005; Simpson et al., 2012). Conversely, completing the CPT puts greater demands on non-executive processes, for example, on visual attention and processing speed - a problem of task impurity (Miyake & Friedman, 2012). Thus, the day-night task may have provided a more sensitive measure of changes in response inhibition after video viewing.

Alternatively, the pattern of findings might stem from the differences in the type of response inhibition that is captured by the day-night task and the CPT. The former is a measure of *conflict* inhibition, which is required to suppress a well-practised behaviour in favour of making a novel response (Carlson, White, & Davis-Unger, 2014; Van Reet, 2015). In comparison, the latter requires a pause to assess the stimulus against the target before making a response, and therefore the CPT commission errors could be a measure of *delay* inhibition (Van Reet, 2015). Perhaps exposure to impossible attributes of the objects and characters that featured in the unrealistic story (e.g., broom as a mean of transport, anthropomorphic animals) made it easier for the children to make unnatural and novel responses (i.e., say 'sun' to a picture of moon and vice versa) in the subsequent day-night task. However, it did not improve children's ability to delay responding to avoid making errors on the CPT.

Our findings were in contrast to those obtained by Lillard et al. (2015), who found that watching unrealistic events and characters was detrimental to children's subsequent executive performance. An obvious explanation for this discrepancy is the different measures used. In the present study, we used the day-night task, which has particularly high inhibitory demands. In contrast, Lillard et al. used several tasks assessing various executive skills (i.e., delay of gratification, working memory, functional fixedness, inhibitory control, cognitive flexibility). Considering the evidence for divergence between different components of executive function in early childhood (e.g., Caughy, Mills, Owen, & Hurst, 2013; Gandolfi, Viterbori, Traverso, & Usai, 2014; Lerner & Lonigan, 2014; McAuley & White, 2011), it is possible that these components are affected by visual media in different ways. This important proposal needs to be explored in future research.

Previous research has explored the relationship between executive function and understanding of the unrealistic features contained in fantasy and pretence. Processing fantasy involves making sense of unexpected events and managing conflicting mental representations. Thus, it may engage several executive functions, for example, inhibitory control, attentional shifting and delay of gratification (Carlson et al., 2014; Kelly, Hammond, Dissanayake, & Ihsen, 2011; Lillard et al., 2015; Pierucci, O'Brien, McInnis, Gilpin, & Barber, 2014;

Thibodeau, Gilpin, Brown, & Meyer, 2016). Inhibitory control in particular may be required when engaging in pretend play (Kelly et al., 2011). On the one hand, inhibitory control may be required to suppress mental representations of reality during pretend play (Carlson et al., 2014). On the other hand, pretend play is governed by child-imposed rules, and as such, requires substantial self-control (Vygotsky, 1978).

Importantly, the findings of a recent study showed that taking part in a conflict inhibition task had immediate benefits for pre-schoolers' ability to engage in pretence (Van Reet, 2015). Currently, it is not clear whether these effects are bidirectional. However, the possibility that processing unrealistic content delivered via a range of media (e.g., video, books, games and apps) may enhance subsequent executive function should be explored in further research.

This brings us to a more fundamental question about the operation of executive function. Both we and Lillard and colleagues (2015) propose that watching unrealistic content *activates* executive function. But, we propose that this activation continues in a subsequent executive task leading to better performance, whereas Lillard et al. propose that this activation depletes executive function, and so worsens subsequent performance. One line of research, conducted principally with adults, suggests that inhibitory control is depleted when used (resource depletion theory - Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven, Tice, & Baumeister, 1998). However, a recent review of meta-analyses has questioned whether using inhibitory control does actually lead to its depletion (Friese, Loschelder, Gieseler, Frankenbach, & Inzlicht, 2018). Whether using inhibitory control, and other executive functions, leads to their short-term enhancement or depletion is an important empirical question which is yet to be resolved.

The effects of pace and realism on attention

Although our data provide support for the proposal that pace affects some aspects of attention, these effects were moderated by the story's realism. Specifically, exposure to fast pace resulted in quicker reaction times, but only with the video featuring realistic storytelling. Attention is the result of an interaction between stimulus-driven and goal-driven processes (Connor, Egeth, & Yantis, 2004; Egeth & Yantis, 1997; Sarter, Givens, & Bruno, 2001). In the CPT, a salient stimulus is briefly presented, which elicits an automatic orienting response (Posner & Snyder, 2004). The activation of involuntarily attention, triggered in response to audio-visual input, is the key premise of the passive viewer theory (Singer, 1980). Frequent scene changes and other audio-visual features automatically activate children's attention in a fast-paced programme. In this way, initial processing of the CPT stimuli parallels processing of a fast-paced video; attention is driven by visually salient stimuli appearing on the screen. However, the further allocation of attentional resources during the CPT depends on the particular goal (the task instructions which determined the target) and requires cognitive effort (Egeth & Yantis, 1997). This additional goal-driven processing slows responding, as more time is needed to assess the relevance of the stimulus in relation to the task goal. Conversely, failure to engage executive processing results in automated responding triggered by perceptual input, which in turn, shortens response times (Manly, Davison, Heutink, Galloway, & Robertson, 2000).

Both the results of Lillard et al. (2015) and our findings pertaining to inhibitory control, indicate that watching videos featuring realistic story does not activate executive processes as much as watching videos presenting unrealism. Together, these data suggest that watching the fast-paced video featuring a realistic story may require less cognitive effort. This reduced activation of executive processes during viewing could have further resulted in less processing during the subsequent CPT. The children, who watched a fast-paced version of the realistic story, “allowed” their performance to be driven by the visually salient onset of the trial (reduced executive processing), and so responded faster.

This interpretation of our findings is congruent with the pattern of results observed in the studies in which attention was operationalised with the frequency of changes between activities during free-play (Geist & Gibson, 2000; Kostyrka-Allchorne, Cooper, Gossmann, et al., 2017). In those two studies, exposure to a fast-paced programme resulted in more frequent shifts between toys, thus suggesting quicker processing of information about a particular toy before moving on to the next activity. Unstructured play activates executive processing, as during play, children set and maintain their own goals. However, unlike a formal attention task (when children are instructed what to do by an experimenter) during free-play, the goals are self-imposed (Barker et al., 2014). Therefore, more frequent changes between the objects of play activity could have been a result of poorer activation of executive processing, which compromised children’s ability to engage in goal-directed behaviour.

In sum, we propose a modified passive viewing hypothesis. That is, children’s attention to the programme is maintained by the perceptual salience of on-screen stimuli, but only in the absence of the features that could enhance executive processing during viewing. Considering the possibility that some features (e.g., fantasy) delivered via visual media have the potential to attenuate the detrimental effects of fast pace, future research should explore the relationships between different types of programme features and children’s cognition in more detail.

Limitations

Producing our own videos allowed us to detect nuanced changes in performance, which depended on both unique and interactive effects of story realism and video pace. Yet despite our efforts to control for confounding variables, there remains an uncertainty about the presence of other factors, which could have *mediated* the observed effects. For example, it could be that the presence of fantasy in the stories increased children’s motivation, and this in turn improved their inhibitory performance, rather than fantasy activating inhibitory control directly. There is some evidence that fantasy can increase the engagement and learning, at least in older children (Parker & Lepper, 1992; Rose, Merchant, & Bakir, 2012).

Moreover, considering Anderson and colleagues' active viewer theory (e.g., Anderson & Lorch, 1983) other potential variables could have affected children's processing of the videos and, consequently, their task performance. Namely, these are the comprehensibility of the content, the familiarity with the story characters, the viewing environment and the enjoyment during viewing. To distinguish the effects of story realism from the effects of other variables, this study should be replicated using multiple videos that contain varied amount of unrealistic content. Disentangling the effects of the many factors that are involved in processing of the visual media and their associations with children's cognitive outcomes is a key challenge for future research in this field.

It is also important to consider that the children's post-video day-night task performance could have been moderated by their pre-video exposure to the same task. Huber, Yeates, Meyer, Fleckhammer, and Kaufman (2018) have recently proposed that completing the same task at baseline might attenuate the potential effects of media exposure in the post-test assessment. Similarly, post-video, day-night task performance could have been affected by taking part in the CPT immediately before. It is therefore important that future work in this area addresses the question whether the effects of media are moderated by prior task exposure or the order of task presentation. We also need to acknowledge the potential limited generalizability of our findings. First, producing experimental materials limited the choice of editing features and did not allow investigating the effects of animated fantasy, which is a staple of children's television. Second, the experimental videos used in our study were relatively short in comparison to a typical children's programme. It is therefore possible that longer exposure would have different effects for subsequent performance. The possibility that programme duration affects subsequent task performance should be explored in future studies. Third, we used the CPT to examine children's *optimal* attention. Such formal laboratory measures have been found to be only moderately related to standardised ratings of *everyday* hyperactive-impulsive behaviour (Barker et al., 2014). Finally, although traditional television remains the favourite type of media platform for under-sixes (Kostyrka-Allchorne, Cooper, & Simpson, 2017), children now have access to a variety of digital devices (including tablets and smartphones), which allow convenient access to television content and other kinds of video. Nevertheless, the effects of video may be similar across digital devices, and it remains important to investigate the effects of screen-time on developmental outcomes.

Conclusion

Children's executive function maybe affected more by a story's realism than the video pace, whereas attention is sensitive to the interactive effects of realism and pace. The results reported in this article suggest that watching story-like programmes with embedded fantasy results in improved executive control. Moreover, in the absence of cognitively stimulating features, fast pace results in quicker but less reflective responding. Together, our results demonstrate that watching a short video of an actor reading a story has immediate but modest consequences for children's performance on attention and executive function tasks. Future research should aim to tease out further how different components of television audio-visual form and narrative affect children's optimal as well as everyday cognition.

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