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The effect of animation on comprehension and interest

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Abstract Although animations are believed to be effective in learning and teaching, several studies have failed to confirm this. Nevertheless, animations might be more attractive and motivating. Fourth and sixth grade students learned the operation of a bicycle pump from graphics that were: (i) presented simultaneously; (ii) presented successively; (iii) self-paced, or (iv) animated. The presentation mode affected evaluation of perceived comprehensibility, interestingness, enjoyment and motivation, but not comprehension test score. Fourth graders who were low in need for cognition rated the animations as more enjoyable and motivating, whereas sixth graders rated self-paced graphics as more interesting and motivating. The evaluations of sixth graders correspond to results of many studies on learning. Animations are not more effective than equivalent static graphics in learning, and they are not seen as more motivating by sixth graders.

Keywords animation, comprehension, interest, need for cognition, self-paced presentation, static graphics.

The effect of animation on learning

As multimedia and computer graphic technology have developed and become widely available, animations have been increasingly incorporated into learning materials. Both researchers and educational practitioners have believed that animation would facilitate learning. Reasoning *a priori*, animations are more realistic for showing change; they can demonstrate in action the systems to be taught. Because animations can show change in time, they are thought to be natural and effective for conveying change in time (Nielsen 1995; Tversky *et al*. 2002).

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Several studies have compared animated graphics with static graphics directly. Some have claimed that students learning from animated graphics outperformed those learning from static graphics, for example, for understanding algebra rate problems (Baek & Layne 1988), the circulatory system (Large *et al.* 1996), Newton's laws of motion (Rieber 1990, 1991a,b), and electronic circuits (Park & Gittelman 1992).

Although there may be domains where animation is an important characteristic of the domain that needs to be understood by learners (e.g. changes of the system that occur in parallel and that are thus hard to depict by static graphics), closer comparison of the graphics in these studies reveals that the animated graphics portrayed more information than the static ones (Tversky *et al*. 2002). In particular, Tversky *et al.* argued that the animated graphics included additional information fine-grained actions of the system, information not depicted

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in the static graphics. In studies equating the information in animated and static graphics, no differences in memory and comprehension have been found (Morrison & Tversky 2001). Many other studies have failed to find benefits of animated over equivalent static graphics (e.g. Rieber 1989; Rieber & Hannafin 1988; Byrne *et al.* 1999; Hegarty *et al*. 2002).

There are even potential disadvantages of animated graphics over static ones. Because animations change over time, they cannot be inspected and re-inspected the way static diagrams can. The information in animations may be fleeting and hard to process (Tversky *et al*. 2002). In addition, motion itself attracts attention, so less important but more active aspects of animations may override the voluntary control of attention to the important aspects (Yantis & Jonides 1990). Animations are often complex, and novices may not know which are the important features to attend to and process. Learners may be so overwhelmed by the complexity that they give up and regard the animations passively rather than actively. In summary, it is possible that animations may distract attention and interfere with deeper processing, therefore affecting comprehension negatively.

Animation and interest/motivation

Although the effect of animated graphics on learning is still controversial, one of the main reasons for the growing popularity of animation seems to be the belief that animation is more interesting, aesthetically appealing, and therefore more motivating. Some research has shown that animations are much preferred for their perceptual attractiveness (Perez & White 1985; Rieber 1991a; Sirikasem & Shebilske 1991) although this is not universal. If students find animations interesting, the reasoning goes, they will spend more time and resources attending to them.

Interestingness, however, is not a unitary concept. At least two different types of interest can be distinguished: *emotional interest* and *cognitive interest*. According to Kintsch (1980), emotional interest is created by events that are arousing. Cognitive interest, on the other hand, is produced by the relationships between incoming information and background knowledge. Previous research on cognitive interest indicates that interest can be generated by the intellectual activity of resolving incongruity, such as that entailed in making inferences (Schank 1979; Kintsch 1980; Mandler 1982; Kim 1999). These finding's suggest that static graphics are more likely to increase cognitive interest than animated graphics because static graphics require the learner to generate more inferences to fill the gaps between them. On the other hand, animated graphics are more likely to increase emotional interest than static graphics because animation may induce higher arousal levels.

Researchers studying text processing have used the term *seductive details* to refer to interesting but irrelevant details that are added to learning material to make it more attractive (Garner *et al.* 1989; Wade & Adams 1990; Garner *et al.* 1992). Seductive details show a negative effect on learning (Mayer 2001). For example, Harp and Mayer (1997, 1998) found that adding entertaining graphics to a scientific text increased emotional interest but not cognitive interest. One possible explanation for the absence of effects of seductive details on cognitive interest is that the additional information may cause cognitive overload and distract the reader from the important information. Seductive details may not require the cognitive resolution that is the basis for cognitive interest.

This analysis of seductive details may be extended to the presentation of graphic information. Animated graphics are bound to have more information about the form and details of movement than static graphics. However, the dynamic details that characterize animated graphics may only be seductive details that provide emotional interest but distract learners from making sense of the material. Animated graphics, in essence, have seductive details that increase emotional interest, but not cognitive interest.

Another important aspect of a learner's motivation and interest is controllability or interactivity. One strategy for enhancing the learner's motivation is to increase his or her sense of control and self-determination by providing choice or locus of control (e.g. Nuttin 1973; Deci & Ryan 1985). It has been well documented that individuals offered choice show more enjoyment, better performance, and greater persistence at a variety of activities due to the increased interactivity or controllability (e.g. Langer & Rodin 1976; Perlmuter & Monty 1977; Malone & Lepper 1987). For example, Cordova and Lepper (1996) demonstrated that provision of choice in multimedia learning material enhanced students' intrinsic motivation.

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Individual differences

The effect of animation on learning and motivation may vary depending on individual differences in need for cognition (NFC), age, and spatial ability.

Need for cognition

Kim (1999) found that cognitive interest is based in bridging inferences, in finding relationships that are not explicit. Iran-Nejad (1987) also argues that cognitive interest is generated by intellectual activity of the individual. This suggests that there might be individual differences in cognitive interests depending on the desire to engage in intellectual activity. One promising dispositional factor is the NFC. NFC refers to an individual's tendency to engage in and enjoy effortful cognitive endeavours (Cacioppo & Petty 1982; Petty & Cacioppo 1986). Previous research has shown that individual differences in the NFC affect persuasion and attitude (Cacioppo *et al.* 1983; Haugtvedt *et al.* 1992). It is highly plausible that individual differences in NFC would influence the effectiveness of, and the preference for, animation. That is, high-NFC learners might prefer static graphics to animated graphics because they would generate inferences to fill in the gaps between the static graphics. In contrast, low-NFC learners might prefer animated graphics to static graphics.

Age

Individual differences in NFC with respect to the present animations may interact with age because there are likely to be developmental differences in inferential processing. Older students (sixth graders) may be able to generate inferences for static graphics whereas younger students (fourth graders) may be able to generate inferences for static graphics only when they are high-NFC. Thus, it is hypothesized that younger students are more likely to prefer animated graphics to static graphics, whereas there may be no differences in preference and comprehension between animated graphics and static graphics for older students.

Spatial ability

Although learning from graphics depends on spatial abilities such as the ability to visualize and mentally rotate objects, there are conflicting results as to whether low-spatial-ability learners or high-spatial-ability learners would benefit most from animated graphics. Mayer and Sims (1994) proposed an ability-as-enhancer hypothesis which argues that animation should bene fit high-spatial-ability learners more than low-spatial-ability learners. Alternatively, Hays (1996) proposed an ability-as-compensator hypothesis, which predicts that animation should benefit the low-spatial-ability learners more than high-spatial-ability learners.

As there is evidence for both hypotheses, that graphics primarily benefit high-spatial-ability learners and that graphics primarily benefit low-spatial-ability learners, it seems likely that the conflicting results are due to the nature of the graphics and the type of information that is meant to be extracted from them. Indeed, for materials similar to the present ones, low ability participants are able to extract structural information but not functional information from graphics (J. Heiser & B. Tversky, unpublished). Because the relationship between individual differences in spatial ability and animation is complex depending heavily on the importance of 3D information for constructing a reasonable mental model, spatial ability is used only as a covariate in the present study.

The effect of animation on comprehension and interest

This study investigated comprehension of, and attitudes toward, four different graphic presentations (simultaneous presentation of static graphics, successive presentation of static graphics, self-paced presentation of static graphics, animated presentation of graphics) among fourth and sixth graders who differed in their NFC. Three research questions motivated this study. First, are there effects of animated graphics on comprehension, ratings of interestingness, and motivation to learn? Because of previous failures to find benefits of animated over static graphics on learning, we did not expect strong effects on comprehension. However, we did expect effects on interestingness and motivation because animations have seductive details. Second, are there interactions between presentation mode of the learning material and NFC of the learner? Here, we expected that students high in NFC might prefer static graphics, as these require bridging inferences. Third,

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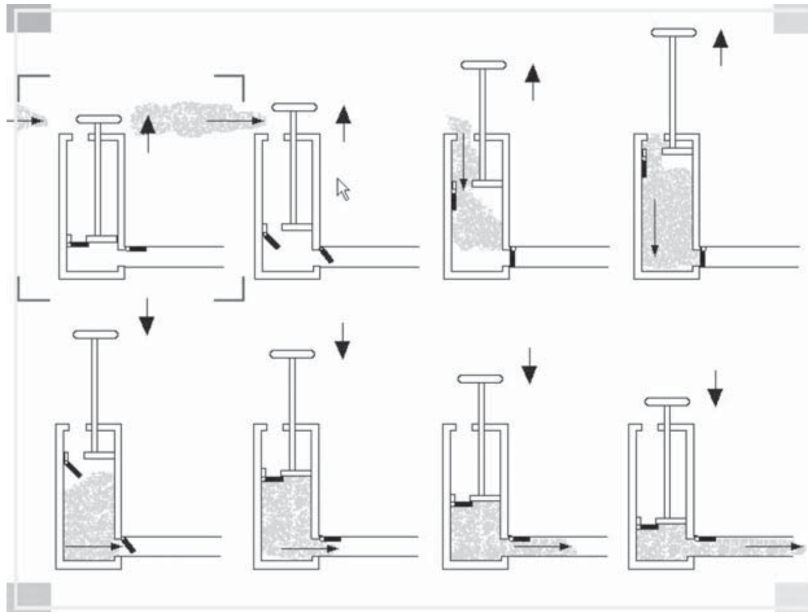

Fig 1 Eight static frames from the bicycle pump animation and narration.

are there any developmental differences in comprehension, interestingness, and motivation as they respond to various types of graphic presentation? Older children are naturally expected to learn more effectively irrespective of materials. Older children may also have more general insight into the types of materials that are effective for learning.

Method

Participants and design

The participants were 101 fourth grade students and 107 sixth grade students from a public elementary school, in Seoul. They were randomly assigned to one of four presentation conditions in a 4 (presentation mode) × 2 (NFC level) between-subject factorial design.

Materials

The static version of experimental material was adapted from the static illustration in *The World Book Encyclopedia* (1991) on the operation of a bicycle tire pump. The static graphics consisted of eight black-and-white line-drawings. Figure 1 presents frames from an animated depiction of how a bicycle tire pump works, along with words from the accompanying narration adapted from Mayer and Anderson (1991). The animated version was identical to the one used in the previous studies by Mayer and colleagues (e.g. Mayer & Anderson 1991, 1992; Mayer & Sims 1994).

The experimental materials consisted of four programs depicting the operation of bicycle tire pump that differed only in presentation type:

- *Simultaneous presentation of static graphics* – eight static graphics simultaneously presented with a frame that moved to accompany the narration
- *Successive presentation of static graphics* – one by one presentation of each static graphic with a one second pause between each graphic
- *Self-paced presentation of static graphics* – self-paced one by one presentation of each static graphic
- *Animated presentation of graphics* – continuously presented animated graphics

Each program was coordinated with the narration. The narration consisted of a 32-word description spoken in a male voice. All conditions were created with Macromedia Director.

Spatial ability test

The Vandenberg Mental Rotation Test (Vandenberg & Kuse 1978) was used to measure students' spatial abilities. The test consists of 20 items each with a target block figure and four alternative figures, two of which are three-dimensional rotations of the target. The task is to identify the two rotated versions.

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Need for Cognition scale

The abbreviated version of the Need for Cognition scale was used to assess the degree to which each student engages in effortful cognitive processing (Cacioppo *et al.* 1984). The scale consists of 18 items that contain statements about situations that require self-ratings of demand for cognitive effort. All participants were divided into high and low NFC groups by median split.

Among 101 fourth graders, 53 students were classified as low NFC students and 48 students were classified as high NFC students, whereas 50 students were classified as low NFC students and 57 students were classified as high NFC students for sixth graders. The total number of participants in each condition were as follows: (i) simultaneous static-graphic presentation (for fourth graders, low NFC = 15, high NFC = 11; for sixth graders, low NFC = 17, high NFC = 9); (ii) successive static-graphic presentation (for fourth graders, low NFC = 13, high NFC = 12; for sixth graders, low NFC = 11, high NFC = 19); (iii) self-paced static-graphic presentation (for fourth graders, low NFC = 12, high NFC = 13; for sixth graders, low NFC = 9, high NFC = 12); and (iv) animated-graphic presentation (for fourth graders, low NFC = 13, high NFC = 12; for sixth graders, low NFC = 13, high NFC = 17).

Comprehension test

The comprehension test consisted of 20 true-false questions to assess students' understanding and knowledge both of the structure and the function of the bicycle tire pump. Half the statements assessed structural information and half functional information about the bicycle pump. The questions were taken from J.B. Morrison and B. Tversky, unpublished.

Attitude questionnaire

The attitudinal questionnaire consisted of the following four questions answered on a 5-point scale. Higher values for the subjective ratings mean higher level of perceived comprehensibility, interestingness, enjoyment and motivation.

- Perceived comprehensibility – 'How much do you think you understand the learning material'?
- Interestingness – 'How interesting is this learning material'?
- Enjoyment – 'How much did you enjoy this learning material'?
- Motivation – 'How willingly would you study other learning material through this type of presentation medium'?

Procedure

Participants were given 6 min to complete the Vandenberg mental rotation test. After completing the spatial ability test, participants were administered the Need for Cognition scale (Cacioppo *et al.* 1984). Participants who scored above the median on NFC scale were classified as high NFC and those who scored below the median were classified as low NFC. After being randomly assigned to one of the four presentation conditions, participants viewed the learning material three times. The onset of each presentation was controlled by the participants. When the participants completed viewing the presentation, they completed the attitude questionnaire then answered the comprehension test questions.

Results

Separate 2 (high/low NFC) × 4 (simultaneous static, successive static, self-paced static, animated) analyses of covariance (ANCOVA) were conducted on the comprehension test scores and on the four attitude measures (Perceived comprehensibility, Interestingness, Enjoyment, Motivation) with the Vandenberg mental rotation test score as a covariate. The mean rating or test scores and standard deviations for the five dependent measures appear in Tables 1 and 2. Effect sizes (ES) were computed as Cohen's d.

Comprehension test

For fourth graders, there were neither significant main effects ($F = 1.29$, $P = 0.28$ for presentation type; $F = 0.08$, $P = 0.78$ for NFC) nor interaction effects ($F = 63$, $P = 0.60$) on comprehension test scores. However, for sixth graders, the main effect of presentation type on the comprehension test scores was significant, F (3, 98) = 3.15, MSE = 3.87, $P < 0.05$. LSD tests (based on an alpha of 0.05) indicated that students learning from the simultaneous presentation (M = 10.8) performed more poorly than those learning from the other three types of presentations, which did not differ significantly from one another (M = 12.2, 12.0, 12.0; ES = 0.68, 0.61, 0.56 respectively). There was no significant main effect of NFC ($F = 1.51$, $P = 0.22$) and interaction effect

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Table 1. Mean ratings and test score for interest, motivation and comprehension for fourth graders (standard deviations are provided in parentheses).

	Simultaneous	Successive	Self-paced	Animated	Total
Comprehension test score					
Low NFC	11.4 (1.7)	11.3 (1.8)	10.5 (1.0)	11.8 (2.0)	11.3 (1.7)
	$n = 15$	$n = 13$	$n = 12$	$n = 13$	$n = 53$
High NFC	10.5 (2.0)	11.2 (1.5)	11.2 (1.8)	11.8 (2.2)	11.2 (1.9)
	$n = 11$	$n = 12$	$n = 13$	$n = 12$	$n = 48$
Total	11.0 (1.8)	11.2 (1.6)	10.9 (1.5)	11.8 (2.1)	11.2 (1.8)
	$n = 26$	$n = 25$	$n = 25$	$n = 25$	$n = 101$
Perceived comprehensibility					
Low NFC	3.5 (1.1)	3.5 (0.9)	3.7 (1.0)	4.5 (0.8)	3.8 (1.0)
High NFC	3.0 (1.0)	4.2 (0.8)	4.5 (0.7)	4.5 (0.7)	4.1 (1.0)
Total	3.3 (1.0)	3.8 (0.9)	4.1 (0.9)	4.5 (0.7)	4.0 (1.0)
Interestingness					
Low NFC	2.9 (1.0)	3.5 (1.0)	3.6 (0.9)	4.3 (0.9)	3.5 (1.0)
High NFC	3.0 (0.8)	4.2 (1.1)	4.3 (0.6)	4.3 (0.9)	4.0 (1.0)
Total	3.0 (0.9)	3.8 (1.1)	4.0 (0.8)	4.3 (0.8)	3.7 (1.0)
Enjoyment					
Low NFC	3.5 (0.5)	3.5 (0.7)	3.3 (0.7)	4.4 (0.7)	3.7 (0.7)
High NFC	3.6 (1.3)	4.0 (0.7)	4.3 (0.9)	4.3 (1.1)	4.1 (1.0)
Total	3.5 (0.9)	3.8 (0.7)	3.8 (0.9)	4.3 (0.9)	3.9 (0.9)
Motivation					
Low NFC	3.7 (1.0)	4.0 (0.7)	4.0 (1.0)	4.5 (0.5)	4.1 (0.8)
High NFC	3.3 (1.3)	4.1 (0.9)	4.8 (0.4)	4.7 (0.5)	4.2 (1.0)
Total	3.5 (1.1)	4.0 (0.8)	4.4 (0.8)	4.6 (0.5)	4.1 (0.9)

NFC, need for cognition.

between presentation type and NFC ($F = 1.67$, $P = 0.19$).

Perceived comprehensibility

For fourth graders, there was a significant main effect of presentation type on perceived comprehensibility, F (3, 92) = 6.94, MSE = 0.770, $P < 0.001$. Although the main effect of NFC was not significant ($F = 1.05$, $P = 0.31$), the interaction effect of presentation type and NFC was significant, F (3, 92) = 3.49, $P < 0.05$ (see Fig 2). LSD tests indicated that low NFC students gave higher perceived comprehensibility ratings to the animated presentation (M = 4.5) than to any other type of presentation (M = 3.5, 3.5, 3.7; ES = 1.04, 1.77, 0.88 respectively), whereas the high NFC students gave lower perceived comprehensibility ratings to the simultaneous presentation (M = 3.0) than to the other graphic presentations (M = 4.2, 4.2, 4.5; ES = 1.33, 1.74, 1.74 respectively). In contrast, for sixth graders, an ANCOVA revealed that there were neither significant main effects ($F = 0.79$, $P = 0.50$ for presentation type; $F = 0.86$, $P = 0.36$ for NFC) nor interaction effects ($F = 0.29$, $P = 0.83$) in regard to perceived comprehensibility ratings.

Interestingness

For fourth graders, a significant main effect was found for presentation type, F (3, 92) = 9.42, MSE = 0.82, $P < 0.001$. Subsequent LSD tests indicated that the simultaneous presentation (M = 3.0) was rated significantly less interesting than the other types of presentation (M = 3.8, 4.0, 4.3; ES = 0.84, 1.17, 1.53 respectively), which did not differ significantly from one another. A marginally significant main effect was also found for NFC, F (1, 92) = 3.69, MSE = 0.82, $P = 0.058$, with high NFC students rating the learning material as more interesting (M = 4.0) than low NFC students (M = 3.5). The interaction effect of presentation type and NFC was not significant ($F = 1.09$, $P = 0.36$).

For sixth graders, the main effect of presentation type approached significance, F (3, 98) = 2.51, MSE = 0.63, $P = 0.063$. Subsequent LSD tests indicated that the

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Table 2. Mean ratings and test score for interest, motivation, and comprehension for sixth graders (standard deviations are provided in parentheses).

Need for cognition	Simultaneous	Successive	Self-paced	Animated	Total
Comprehension test score					
Low NFC	11.3 (1.9)	12.1 (2.1)	12.8 (1.6)	11.6 (2.2)	11.8 (2.0)
	n = 17	*n* = 11	*n* = 9	*n* = 13	*n* = 50
High NFC	9.9 (2.6)	12.3 (1.9)	11.4 (1.6)	12.4 (2.0)	11.7 (2.1)
	n = 9	*n* = 19	*n* = 12	*n* = 17	*n* = 57
Total	10.8 (2.2)	12.2 (1.9)	12.0 (1.7)	12.0 (2.1)	11.8 (2.0)
	n = 26	*n* = 30	*n* = 21	*n* = 30	*n* = 107
Perceived comprehensibility					
Low NFC	3.9 (1.1)	4.4 (0.9)	4.0 (0.7)	4.0 (0.7)	4.1 (0.9)
High NFC	3.8 (1.3)	4.1 (1.0)	4.5 (0.5)	4.2 (0.6)	4.2 (0.9)
Total	3.9 (1.1)	4.2 (1.0)	4.3 (0.6)	4.1 (0.7)	4.1 (0.9)
Interestingness					
Low NFC	3.5 (0.6)	3.0 (0.8)	3.7 (0.9)	3.1 (0.8)	3.3 (0.8)
High NFC	3.1 (1.3)	3.6 (0.8)	4.1 (0.7)	3.7 (0.7)	3.6 (0.9)
Total	3.3 (0.9)	3.4 (0.9)	3.9 (0.8)	3.4 (0.8)	3.5 (0.8)
Enjoyment					
Low NFC	3.3 (0.5)	3.5 (0.5)	3.6 (0.5)	3.0 (0.8)	3.3 (0.6)
High NFC	3.3 (1.1)	3.5 (0.6)	4.0 (0.7)	3.5 (0.8)	3.6 (0.8)
Total	3.3 (0.7)	3.5 (0.6)	3.8 (0.7)	3.3 (0.8)	3.4 (0.7)
Motivation					
Low NFC	3.7 (1.2)	4.4 (0.5)	4.1 (0.8)	3.7 (0.8)	3.9 (0.9)
High NFC	3.9 (0.9)	3.8 (1.4)	4.4 (0.9)	4.4 (0.8)	4.1 (1.1)
Total	3.8 (1.1)	4.0 (1.2)	4.3 (0.8)	4.1 (0.8)	4.0 (1.0)

NFC, need for cognition.

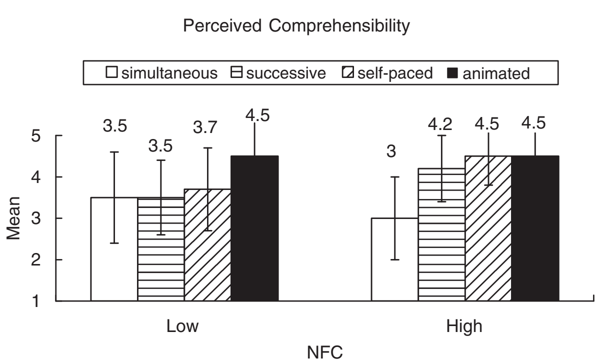

Fig 2 Mean perceived comprehensibility rating across presentation type for fourth graders. NFC, need for cognition.

students with the self-paced presentation (M = 3.9) reported significantly higher interest in the material than those with each of the other types of presentations (M = 3.3, 3.4, 3.4; ES = 0.70, 0.59, 0.63 respectively), which did not differ significantly from one another. A significant main effect was also found for NFC, F (1, 98) = 4.13, MSE = 0.63, $P < 0.05$, with the high NFC students reporting more interestingness (M = 3.6) than the low NFC students (M = 3.3). The interaction effect between presentation type and NFC was not significant ($F = 2.21$, $P = 0.091$).

Enjoyment

For fourth graders, a significant main effect was found for presentation type, F (3, 92) = 4.26, MSE = 0.67, $P < 0.001$. Also, a significant main effect was found for NFC, indicating that high NFC students (M = 4.1) rated the presentations as more enjoyable than low NFC students (M = 3.7), F (1, 92) = 5.68, MSE = 0.67, $P < 0.05$. The significant main effects are better understood in the context of the interaction of presentation type and NFC (see Fig 3). LSD tests indicated that the animated presentation (M = 4.4) was rated significantly more enjoyable than any other types of presentation for low NFC students (M = 3.5, 3.5, 3.3; ES = 1.48, 1.29, 1.57 respectively) whereas there was no significant difference on enjoyment rating among four types of presentations for high NFC students.

For sixth graders, there was a significant main effect of NFC on enjoyment. High NFC students (M = 3.6)

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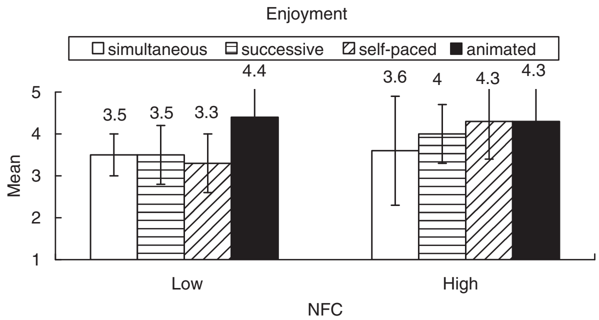

Fig 3 Mean enjoyment rating across presentation type for fourth graders. NFC, need for cognition.

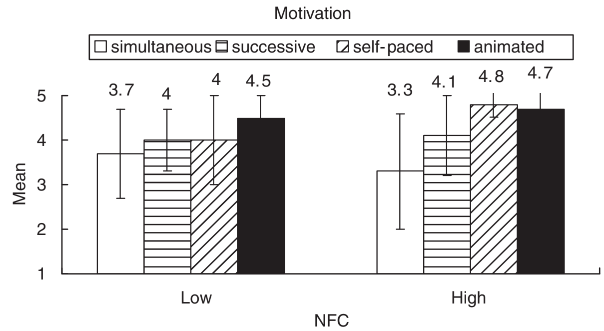

Fig 4 Mean motivation rating across presentation type for fourth graders. NFC, need for cognition.

reported slightly more enjoyment than low NFC students (M = 3.3), F (1, 98) = 3.60, MSE = 0.50, P = 0.061. There was no significant main effect of presentation type (F = 2.26, P = 0.09) and interaction effect between presentation type and NFC (F = 1.14, P = 0. 34).

Motivation

For fourth graders, the main effect of presentation type on motivation was significant, F (3, 92) = 9.30, MSE = 0.66, $P < 0.001$. Although the main effect of NFC was not significant (F = 1.00, P = 0.32), the interaction effect of presentation type and NFC was significant, F (3, 92) = 2.89, $P < 0.05$. LSD tests indicated that low NFC students (M = 4.5) reported significantly higher motivation for the animated presentation than for the simultaneous presentation (M = 3.7) (ES = 1.01). In contrast, high NFC students reported significantly higher motivation for successive, self-paced and animated presentations (M = 4.1, 4.8, 4.7; ES = 0.72, 1.56, 1.42 respectively) than the simultaneous presentation (M = 3.3), and high NFC students reported higher motivation for the self-paced presentation (M = 4.8) than for the successive presentation (M = 4.1) (ES = 1.01) (see Fig 4). For sixth graders, ANCOVA revealed that there were neither significant main effects (F = 0.92, P = 0.44 for presentation type; F = 0.69, P = 0.41 for NFC) nor interaction effects (F = 1.92, P = 0.13) in regard to motivation.

General discussion

Animation, although widely praised, has not proven to be beneficial to learning when compared with static graphics that convey the same information. Even if animations are not more effective, some have claimed that animations are more appealing and therefore make learning more fun. The present experiment examined effects on student learning and evaluation across four types of static and animated graphics teaching the operation of a bicycle tire pumps. Consistent with previous work on learning, animated graphics had essentially no advantage over static ones. There were effects of the type of presentation on students' evaluations, and these interacted with age and with cognitive characteristics of the students.

Fourth graders low in NFC rated animated graphics as more enjoyable and motivating. Low NFC fourth graders maybe see animations sharing task characteristics with television and thus find them higher motivating and enjoyable, because they think that they have to put less effort into understanding the presented contents. In contrast, fourth graders high in NFC did not regard animated graphics as more enjoyable, motivating, or interesting. Sixth graders, on the other hand, irrespective of NFC, found self-paced graphics as more interesting and enjoyable than other forms of graphics, including animated graphics.

Animated graphics, then, are not universally preferred to static graphics. In fact, only younger students who were low in NFC regarded animated graphics as more enjoyable and motivating. One possible explanation for this finding is that fourth graders low in NFC might not be able to generate inferences from static graphics. Animated graphics show the transitions from one frame to another demanding less inferential processing. Fourth graders high in NFC and sixth graders might be able to generate the bridging inferences needed to comprehend static graphics.

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Simultaneous presentation of static graphics was found to be least comprehensible by fourth graders. The other forms of presentation did not differ in perceived comprehensibility ratings. Simultaneous presentation of the graphic learning material may overwhelm learners with detail and distract their attention. This is consistent with the only presentation effect on learning: the older children performed more poorly with simultaneous presentation. Successive graphics present less information at a time, guiding learners' attention. Previous research has found that guiding users' attention to complex graphics facilitates establishing mental models of the material (Betrancourt & Tversky, in press).

High NFC fourth graders also found the self-paced presentation more motivating than other presentations. Students with a high NFC tend to prefer static graphics because they might have high cognitive interest and thus better match their personal preferences. However, this was not the case for fourth graders with low NFC. This suggests that high NFC students prefer interactivity or controllability, that is, they prefer to control information presentation. Overall, students high in NFC found all the learning materials to be more interesting and motivating, consistent with the idea that students high in NFC are more interested in learning. Their evaluations show that they are also more sensitive to the factors that make learning materials effective.

By sixth grade, NFC no longer affects evaluations of the materials. It is as if age and the learning experience that accompanies it compensate for low NFC. The self-paced presentation that allows students to control the rate of input of information and to adapt the speed of information presentation to their speed of cognitive processing and level of understanding is found to be more interesting by all sixth graders. Animated graphics are not given higher ratings. All sixth graders, then, evaluate more highly the self-paced presentation condition that is in fact more effective in learning.

There are several implications for the design of multimedia learning materials from these findings. First, animations need to be used carefully, considering learner's developmental level and level of NFC. Animated graphic are not more effective than static ones, which has been replicated in previous studies (see Tversky *et al*. 2002; for a review). What's more, except for the younger students low in NFC, animations are not evaluated higher on a variety of measures. Programmers and educators may think animations are appealing and beneficial, but actual learners, even young ones, know better.

Second, putting graphic presentation in the control of learners is advisable. These recommendations have the additional benefits of saving costs, as constructing animations are more time-consuming and expensive.

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