Chapter 3
Looking Across Instead of Back and Forth: How the Simultaneous Presentation of Multiple Animation Episodes Facilitates Learning

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3.1 Give It a Try

Assume you are interested in sailing and you want to understand how a yacht can sail. In order to study the subject matter, you obtain a textbook on sailing (e.g., Bark, 2009; Overschmidt & Gliewe, 2009). It describes and depicts some of the physical principles that apply to sailing. Using a bird's eye view, the visualizations present schematic and idealized depictions of the main courses that a yacht can sail in relation to the wind direction. Each of the visualizations shows a compass, the wind direction, the yacht's hull and sail, and various forces that act on the yacht. Figure 3.1 presents the course termed "broad reach" in which the yacht sails off the wind, but not directly downwind. The course termed "close hauled" is displayed in Fig. 3.2. Here the yacht sails as close as possible towards the wind direction.

In broad reach, the yacht's hull is oriented very differently with respect to the wind direction than in close hauled. Is the orientation of the yacht's sail – with respect to both the wind direction and the yacht's hull – also different between broad reach and close hauled? And what about the forces? Which of the forces differ in magnitude and/or direction in broad reach as opposed to close hauled? Would you be able to formulate a higher-order relationship that captures the observable differences?

How did you attempt to provide answers to the questions raised above? Maybe you started by looking at Fig. 3.1 in an effort to first grasp its overall visuospatial arrangement, secondly to distinguish units within the overall arrangement, and

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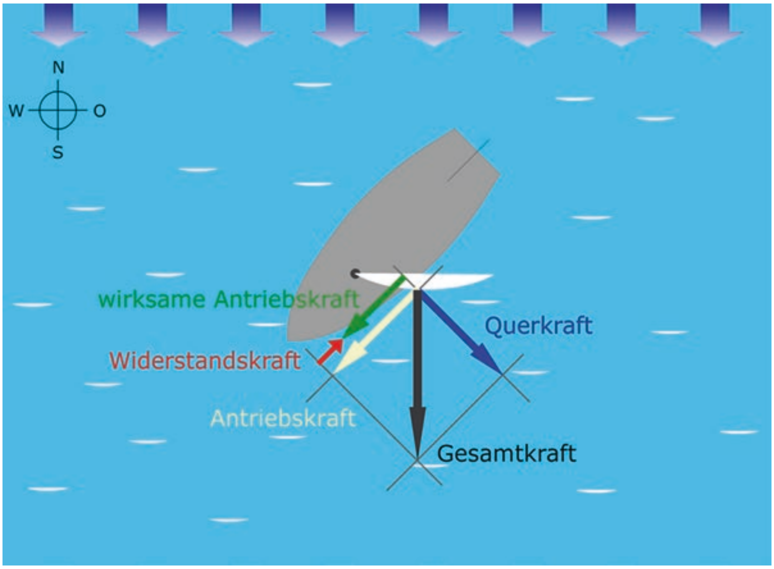

Fig. 3.1 The forces that act on a yacht in broad reach (Gesamtkraft [resultant force], Antriebskraft [driving force], Widerstandskraft [resistance force], wirksame Antriebskraft [effective driving force], Querkraft [drifting force])

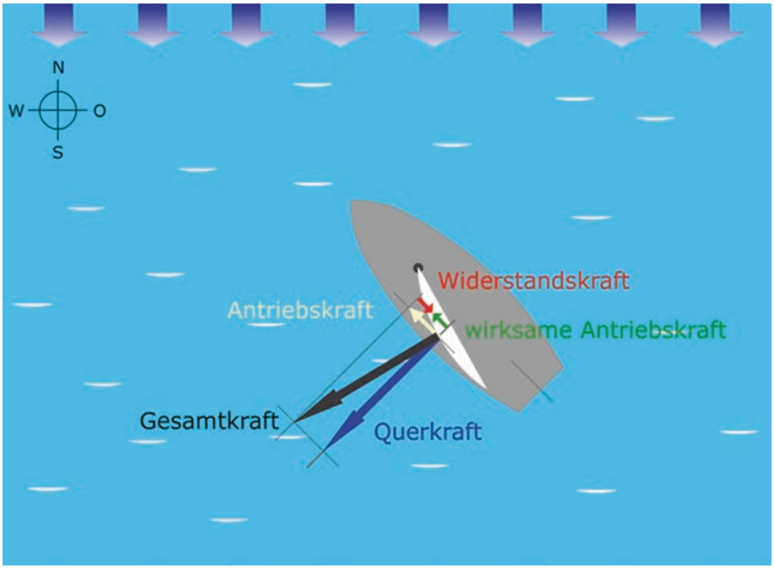

Fig. 3.2 The forces that act on a yacht in close hauled

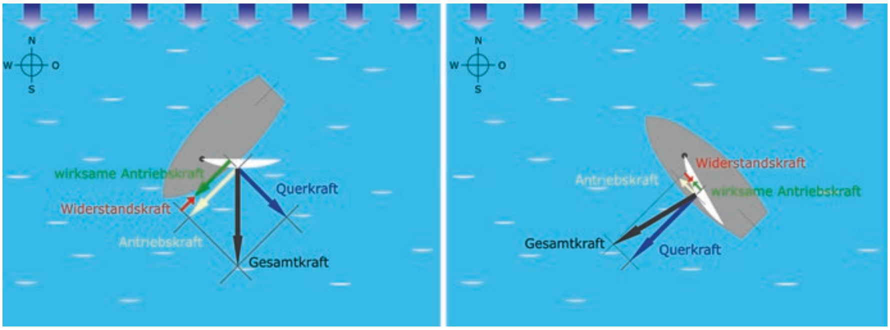

Fig. 3.3 Broad reach and close hauled displayed next to each other, 'optimized' for compare and contrast activities

thirdly to analyze relationships between the identified units. Next, perhaps you looked up Fig. 3.2 and once more invoked these same general processes. During your analysis of Fig. 3.2, you may have tried to recall what was presented in Fig. 3.1. Perhaps you were able to recall some of the information presented in Fig. 3.1, but probably not all of it. You therefore looked up Fig. 3.1 again to refresh your memory and/or to deepen your analysis. You may have also looked back and forth between the two figures several times and might have questioned yourself as to why the figures are set out so poorly. In fact, this type of layout could be considered poor design in respect to static learning material because it violates important multimedia design principles regarding spatial contiguity (cf. Mayer & Fiorella, 2014) and split-attention (cf. Ayres & Sweller, 2014). Perhaps in desperation you even considered folding the pages in such a way that the two figures would be located next to each other because that would make it much easier to compare and contrast the two figures by just looking across them. Please don't damage your book! We have rearranged the figures for you in Fig. 3.3.

3.2 Presenting Multiple Animation Episodes Sequentially or Simultaneously

What you just experienced has some parallels with learning from many behaviorally realistic animations that present multiple episodes one after the other, i.e. sequentially. The sailing animation used in the present study consists of not only two, but four episodes. Each episode depicts one of four courses that a yacht can sail in relation to the wind direction: running (i.e., directly downwind), broad reach, close hauled, and tacking (i.e., sailing against the wind). Any one of these episodes depicts a specific set of local relationships between entities such as the wind direction, the yacht's hull and sail, and the forces that act on the yacht. However, there are also higher-order relationships connecting the individual episodes at a more general level. These relationships link the wind direction to the sail's orientation, the sail's orientation to the directions and magnitudes of the different forces, and the directions and magnitudes of the forces to the yacht's speed. For instance, the relationship that links the wind direction to the sail's orientation could be expressed as "the closer the yachts sails to the wind direction, the closer the sail is oriented towards the hull." In order to develop a comprehensive and hierarchically structured mental model of the animated subject matter, the learner needs to internally represent not only local relationships from within individual episodes, but also higher-order between-episode relationships that encompass information from the animation as a whole. In this situation, constructing a satisfactory mental model requires learners to compare and contrast relevant entities, as well as their local relationships, across individual episodes in order to identify and internalize higher-order relationships.

When episodes are presented sequentially, there can be considerable temporal separation between two instances of event units that need to be compared or contrasted in order to establish inter-episode relations. For example, a learner may wish to compare and contrast material found in the first episode on running with corresponding material in the third episode on close hauled. This would require the learner to extract relevant information from the first episode, store it in memory until the corresponding material in the third episode appears, and then carry out compare and contrast operations between the internal and external representations. In the meantime, the learner is likely to have been engaged in intra-episode processing of the second episode on broad reach in order to make sense of it in its own right. Such intervening processing will most probably result in the overwriting of material stored from the first episode (cf. Lowe, 1999) and thereby severely impede the compare and contrast processes necessary for establishing higher-order relationships.

If the animation was user-controllable, the learner might address this problem by re-inspecting the first episode to identify, extract, and memorize the required material and then skip to the appropriate sequence in the third episode in order to establish a relationship. However, the interrogation involved would not only be inefficient in terms of processing, but also prone to error because of the reliance on memory reliability.

Presenting component episodes of an animation simultaneously, in contrast, offers affordances considerably more suited to identifying and extracting high-level cross-episode relationships than does sequential presentation. However, it requires a major spatiotemporal manipulation of the information that involves a substantial departure from what could actually occur in real life. In reality, it is of course impossible for the same yacht to simultaneously sail on four different courses. Nevertheless, if an animation were to "play tricks with space and time," as suggested by Tversky, Heiser, Machenzie, Lozano, and Morrison (2008), previously unavailable affordances would be offered to the learner. In particular, when different episodes are displayed simultaneously on the same screen, comparisons and contrasts of corresponding material can be made directly and efficiently via scans across the display. The simultaneous presentation of episodes essentially eliminates the need to memorize relevant information over the time taken to present intervening episodes in a sequential animation. It changes the nature of the processing task that learners are required to perform (cf. Zhang & Norman, 1994): instead of requiring them to relate an internal representation to an external representation, simultaneous presentation allows for repeated perceptual switching between two or more external representations. It is also relatively easy for the learner to shift between within-episode and between-episode interrogation without appreciable processing overheads. With respect to the animation as a whole, simultaneous presentation allows learners to move relatively seamlessly between different levels of relationship which should help in building a more coherent, hierarchically structured mental model of the subject matter.

3.3 Different Types of Animation and Inductive Processes

Many learning tasks require students to induce higher-order relationships from learning material such as expository animations. According to Holland, Holyoak, Nisbett, and Thagard (1986), induction encompasses "... all inferential processes that expand knowledge in the face of uncertainty" (p. 1). A major goal of induction is "… to learn about the variability of the environment" (Holland et al., 1986, p. 22). In order to learn about the variability – and constancy – of the environment, students need to recognize both differences and regularities across varying situations. Regularities can rely on shared features of entities as well as on shared relations between entities (cf. Klauer & Leutner, 2012; Klauer & Phye, 2008). According to Klauer and Leutner (2012), compare and contrast processes are the 'silver bullets' for identifying such regularities.

Educational research has investigated learning from a diverse range of expository animations (for a recent review see Ploetzner & Lowe, 2012) and it is evident that there are many different approaches to the presentation of information in animations. Even the animation episodes used in the present study could be displayed in many different ways (cf. Fig. 3.4): each episode could be presented with or without explanatory text, only a single episode or multiple episodes could be shown, and multiple episodes could be presented either sequentially or simultaneously – to mention only a few of the many possibilities. How then does a student need to process each type of presentation in order to learn successfully?

One important type of expository presentation consists of animations that are accompanied by verbal explanations. The explanations might be provided to the learner in either written or spoken form. According to the modality principle (cf. Ginns, 2005; Low & Sweller, 2014; Mayer, 2009), students learn more successfully from animations with narration than from animations with on-screen text. For instance, Kombartzky, Ploetzner, Schlag, and Metz (2010), as well as Ploetzner and Schlag (2013), investigated how learning from the four sailing episodes can be supported by a cognitive learning strategy when the episodes are presented one after the other and are accompanied by spoken explanations (see also Ploetzner & Breyer, 2017, this volume). Commonly the explanations spell out relevant entities, the features of these entities, and the relations between them. That is, in a narrated anima-

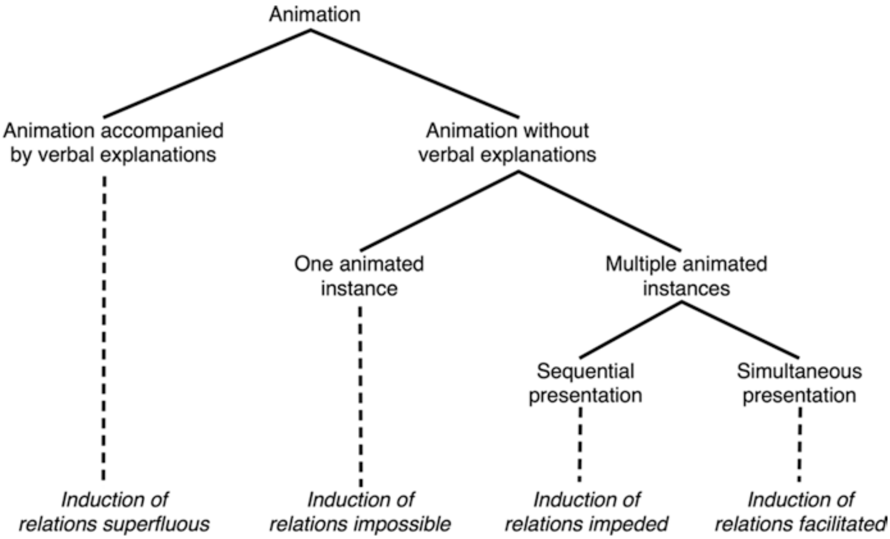

Fig. 3.4 Different types of animation and how they are related to inductive processes

tion, the learner might not be required to induce the regularities in the animated subject matter by her- or himself. According to the Cognitive Theory of Multimedia Learning (CTML; Mayer, 2009, 2014), the learner needs to mentally construct a pictorial and a verbal model by processing the corresponding external representations and then integrating both mental representations into one coherent mental model of the animated subject matter. Therefore, in order to understand the relevant relationships, the learner is required to significantly engage in inter-representation processing.

A second important type of expository animation is made up of animations that are not accompanied by verbal explanations. In this case, the learner is required to recognize the regularities in the animated subject matter without assistance from a narration. According to the Animation Processing Model (APM; Lowe & Boucheix, 2008, 2011, 2017, this volume; Lowe & Schnotz, 2014), learning from animations without verbal explanations progresses as a cumulative activity in which bottom-up and top-down processes interact in order to construct an increasingly comprehensive mental model of the animated subject matter. If the learner, however, lacks relevant domain-specific prior knowledge, then her or his activities will be mostly limited to bottom-up processes. That is, the learner starts with breaking down the continuous flux of information in the animation into individual event units (Phase 1 of the APM) and then successively combines them into broader regional structures (Phase 2 of the APM). Subsequently, the learner could proceed to link regional structures by establishing higher-order relationships that may cover the animation's entire spatial and temporal scope (Phase 3 of the APM). If the learner does not possess the required domain-specific prior knowledge, and does not receive complementary information such as verbal explanations, it is rather unlikely that she or he will be able to progress to Phases 4 and 5 of the Animation Processing Model (cf. Lowe, 2004). Therefore, in order to recognize the relevant relationships, especially in Phase 3 of the APM, the learner needs to engage in considerable intra-representation processing.

Expository animations very often visualize just one instance of a dynamic process (cf. Ploetzner & Lowe, 2012). That is, the animation displays the process in just one specific situation. For instance, an animation shows just one course that a yacht could sail in relation to a specific wind direction. Because a single instance of a process does not reveal the process's variability, the learner can recognize neither differences nor regularities. The induction of higher-order relationships is impossible under these circumstances. However, if an expository animation visualizes multiple instances of a dynamic process, the learner can compare and contrast the different instances in order to identify differences between the instances as well as regularities across the instances. In this case, the design of the animation might either impede or facilitate the required compare and contrast activities.

The sequential presentation of multiple animation instances demands that the learner selects information from one instance, stores it in memory until the corresponding entities in another instance appear, and then compares and contrasts the internal and external representations. In the meantime, the learner may process additional instances and further burden her or his working memory. Thus, it is likely that the cognitive processes necessary for inducing higher-order relationships are impeded by the sequential presentation of multiple animation instances. Presenting multiple animation instances simultaneously, in contrast, offers affordances to the learner that are considerably better suited to supporting the required cognitive processes. For instance, the comparing and contrasting of corresponding entities can be done directly and efficiently via scans across the display. Furthermore, the need to memorize information is fundamentally reduced. The learner can also easily shift from within-instance analysis to between-instance analysis without noticeable processing overheads. Therefore, the compare and contrast processes necessary for inducing higher-order relationships should be facilitated by the simultaneous presentation of multiple animation instances. Figure 3.5 shows how the four sailing episodes are presented in one display.

3.4 Study

Ploetzner and Lowe (2014) conducted an experimental study in order to investigate how the sequential and simultaneous presentation of multiple animation episodes influences the learning of higher-order relationships.

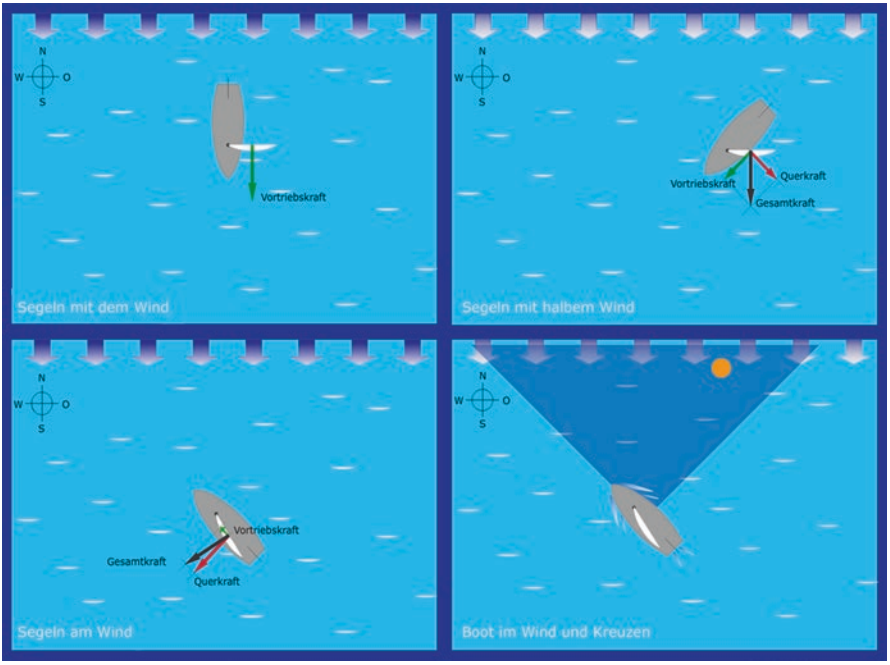

Fig. 3.5 Four animation episodes displayed simultaneously

3.4.1 Design and Hypotheses

Learning from two different versions of a sailing animation was investigated. Both versions consisted of four animation episodes. Each episode portrays a course that a yacht can sail in relation to the wind direction: running, broad reach, close hauled and tacking. While one group of students learned from a sequential presentation of the four episodes (sequential group), another group of students learned from a simultaneous presentation of the same episodes (simultaneous group). Pre- and posttests were administered before and after the learning sessions.

As delineated above, due to the specific requirements and affordances of each presentation, it was hypothesized that the students would process the sequential and simultaneous presentations in different ways. In particular, it was assumed that the simultaneous presentation would result in more visual transitions between the individual episodes than would the sequential presentation. That is, the affordances offered by the simultaneous presentation with respect to comparing and contrasting different episodes should be reflected in the frequency with which the students shifted their visual attention from one episode to another. Furthermore, it was hypothesized that the simultaneous presentation would lead to more bi-directional visual transitions between the different episodes than would the sequential presentation. While simultaneously presented episodes enable learners to directly shift their visual attention between episodes in either direction with equal ease, sequentially presented episodes are likely to favor a more linear processing of the episodes. Finally, it was assumed that the simultaneous presentation would result in more successful learning of higher-order relationships than would the sequential presentation. Because simultaneously presented episodes facilitate necessary compare and contrast processes, they should therefore support the identification of higher-order relationships of the animated subject matter.

3.4.2 Participants, Material, and Procedure

A total of 60 pre-service teacher students volunteered for the study. They received financial compensation for their participation in the study. None of the students who participated in the study had experience in sailing. The students were randomly assigned to the sequential group (25 female and 5 male students, mean age = 21.83 years, *SD* = 2.15) and the simultaneous group (26 female and 4 male students, mean age = 22.00 years, *SD* = 3.43). The eye movements of eight randomly selected students from each group were recorded while they studied the animation episodes.

The students whose eye movements were not recorded participated in groups of up to four individuals, whereas the students whose eye movements were recorded participated individually. Each student was individually seated in front of a computer. To begin, the students completed a pretest that consisted of six items assessing the students' prior knowledge of the principles that apply to sailing. Next, the students studied three printed pages that depicted and explained the graphic entities shown in the animations: a compass, arrows indicating the wind direction, an arrow representing the magnitude and direction of a force, a parallelogram and how it is used to resolve a force into its component forces, and a buoy that the yacht is to reach by tacking. Thereafter, printed instructions informed the students that they could study the animation for up to 9 min, make use of the media player to start, stop, forward and rewind the animation, and watch the animation as often as they wished within the limits of the learning time. During the subsequent learning phase, each student watched the animation by taking advantage of a standard media player on the computer. Lastly, the students completed a posttest. The test contained 14 multiple-choice items that were provided in a verbal format, as well as 10 open items that were presented in a mixed verbal-graphic format. Each item required the students to make use of higher-order relationships that bridge two or more sailing courses, as well as to apply these relationships to sailing courses different from those visualized in the animations.

Students' eye movements were recorded while they watched the animation. The recording device was a SensoMotoric Instruments (SMI) RED binocular remote eye tracker. It consisted of a 22 in. widescreen display with a resolution of 1680 px. (width) × 1050 px. (height), infrared light emitting diodes, and eye tracking cameras. For each student, a nine-point calibration procedure was conducted until horizontal and vertical accuracy was at least 1.0°. In the sequential group, average horizontal and vertical accuracies were $M = 0.44°$ ($SD = 0.17°$) and $M = 0.65°$ ($SD = 0.15°$) respectively. In the simultaneous group, average horizontal and vertical accuracies were $M = 0.58°$ ($SD = 0.12°$) and $M = 0.39°$ ($SD = 0.27°$). After calibration, eye movements were recorded at a sampling rate of 60 Hz. In addition, the displays on the computer screens were recorded using the SMI Video Analysis Package, a program that permits the capture and analysis of dynamic stimuli. With respect to the recorded eye movements, three kinds of gaze-based events were distinguished: fixations, saccades, and transitions. Fixations were defined as events in which the gaze remained for at least 80 ms within a maximum radius of 100 pixels (cf. Blignaut & Beelders, 2009). Saccades were defined as gaze movements from one fixation to another fixation. Transitions were defined as saccades that take place between areas of interests, i.e. they start in one area of interest and end in another area of interest (cf. Holmqvist et al. 2011).

The SMI analysis software BeGaze was used to determine how often the students performed saccades within and transitions between different areas of interest. The analysis was conducted at two different levels of detail. At the first level, four areas of interest were defined within the display. Each area of interest covered the complete spatial region and temporal extent of one of the four sailing courses: running, broad reach, close hauled, or tacking. That is, whenever a sailing course was visible in the screen capture, the corresponding area of interest was active. For all screen captures from the sequential animation, only one area of interest was active at a time. However, for captures from the simultaneous animation, all areas of interest were active at once. Figure 3.6 shows the four areas of interest for a capture from the simultaneous animation.

At the second, more detailed level, three areas of interest were defined. These areas referred to the sailing courses running, broad reach, and close hauled. Each area of interest covered the spatial region and temporal extent of the corresponding course in which the yacht's hull, the sail, and the different forces are shown. Because no forces were shown in the fourth course, tacking, this course was excluded from the analysis. Figure 3.7 shows an area of interest for a capture taken from the sequential animation. For both levels of detail, we determined the frequencies of saccades that took place within the different areas of interest as well as the frequencies of transitions that took place between the different areas of interest. Due to the limits of the eye tracker's resolution, it was not possible to conduct a satisfactory analysis at an even more fine-grained level for individual components such as the sail and the single forces.

3.4.3 Results

Table 3.1 shows the transition matrices for the areas of interest that covered the complete sailing courses. The sequential group ($M = 1340.5$, $SD = 198.6$) produced significantly more fixations overall than the simultaneous group ($M = 1169.3$, $SD = 76.0$; $t(14) = 2.28$, $p < 0.05$; $d = 1.13$). The sequential group ($M = 1003.5$, $SD =$

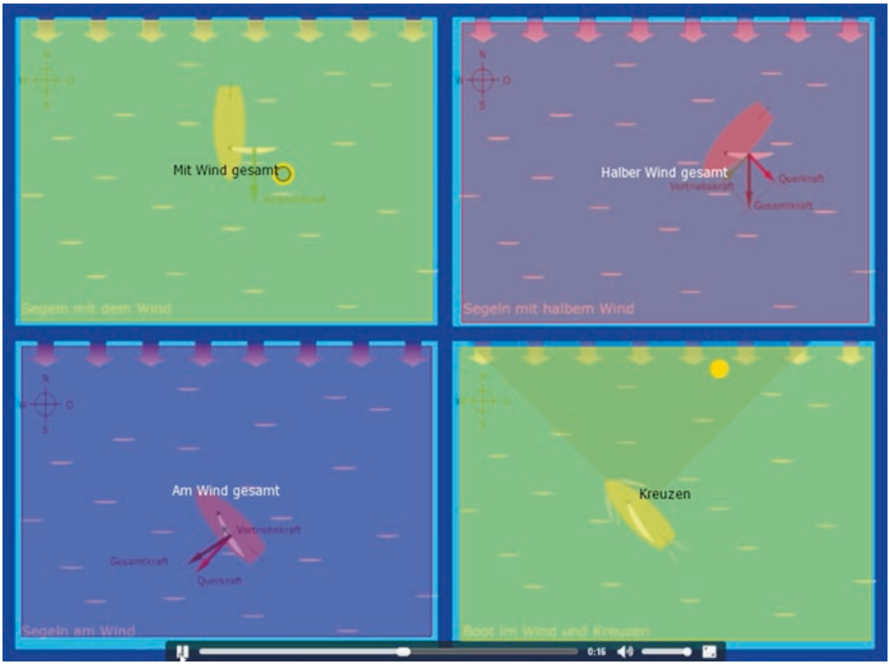

Fig. 3.6 Four areas of interest that cover the complete sailing courses in the simultaneous animation

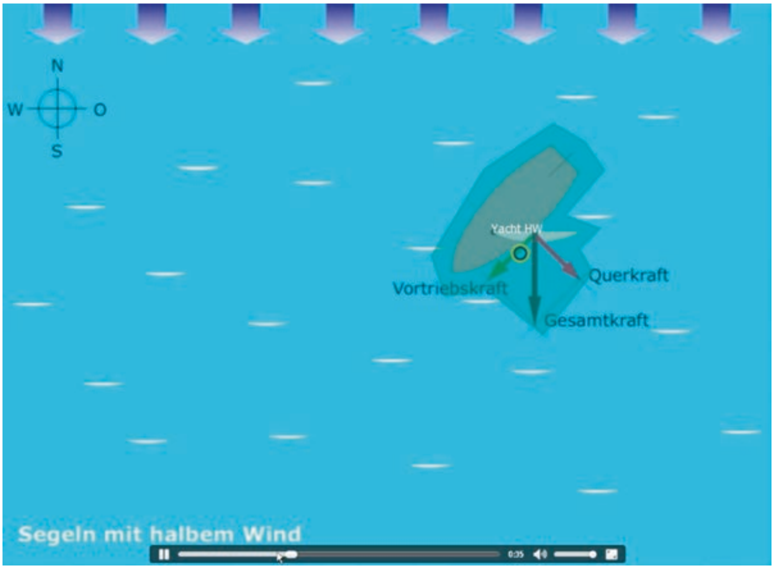

Fig. 3.7 An area of interest that covers specific details of a sailing course in the sequential animation

Table 3.1 The average frequencies (*M*) and standard deviations (*SD*) of the saccades within the areas of interest (values located on the principal diagonal) and the transitions between the areas of interest (values located above and below the principle diagonal)

		Running		Broad reach		Close hauled		Tacking	
Group	AOI	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Sequential	Running	146.6	76.5	7.0	3.3	0.3	0.7	0.5	0.9
($n = 8$)	Broad reach	2.3	2.6	260.5	71.5	10.0	3.0	0.1	0.4
	Close hauled	0.5	1.0	4.3	3.2	267.0	79.0	11.8	6.3
	Tacking	1.8	2.6	0.5	1.4	6.6	8.7	283.9	52.7
Simultaneous	Running	77.4	28.0	18.6	5.7	11.6	4.5	2.9	2.0
($n = 8$)	Broad reach	16.4	6.0	150.9	41.0	13.0	5.0	12.4	6.0
	Close hauled	13.5	6.5	7.9	5.6	205.5	56.1	21.1	10.5
	Tacking	2.8	2.3	11.6	5.0	17.9	8.9	182.4	56.1

230.7) also showed significantly more saccades and transitions (i.e., saccades and transitions across the complete transition matrix) than the simultaneous group (M = 765.8, SD = 95.7; t-test for independent groups with inhomogeneous variances, $t(9.3) = 2.69$, $p < 0.05$; $d = 1.35$).

As predicted, the sequential group ($M = 45.5$, $SD = 22.6$) exhibited significantly fewer transitions between the different areas of interest (i.e., values located above and below the principal diagonal of the transition matrix) than the simultaneous group ($M = 149.6$, $SD = 25.5$; $t(14) = -8.64$, $p < 0.001$; $d = 4.32$). Figure 3.8 exemplifies transitions that occurred between different episodes during learning from the simultaneous animation. Conversely, the sequential group ($M = 958.0$, $SD = 215.2$) exhibited significantly more saccades within the different areas of interest (i.e., values located on the principal diagonal of the transition matrix) than the simultaneous group ($M = 616.1$, $SD = 99.46$; $t(14) = 4.08$, $p < 0.01$; $d = 2.04$). Furthermore, the sequential group made 85.7% more transitions in one direction (i.e., transitions located above the principal diagonal of the transition matrix; $M = 29.6$, $SD = 9.5$) than in the opposite direction (i.e., transitions located below the principal diagonal of the transition matrix; $M = 15.9$, $SD = 13.6$). In contrast, the simultaneous group made only 14.7% more transitions in one direction ($M = 79.6$, $SD = 13.2$) than in the opposite direction ($M = 70.0$, $SD = 13.3$). This difference between the two groups is significant (t-test for independent groups with inhomogeneous variances, $t(7)$ = 2.66, $p < 0.05$; $d = 1.33$).

The results found with respect to the areas of interest that covered the complete sailing courses were entirely consistent with the results yielded with respect to the areas of interest that only covered the yacht's hull, the sail, and the different forces. Table 3.2 presents the corresponding transition matrices. Again, the sequential group ($M = 138.0$, $SD = 42.9$) showed significantly more saccades and transitions than the simultaneous group ($M = 69.9$, $SD = 33.8$; $t(14) = 3.53$, $p < 0.01$; $d = 1.76$).

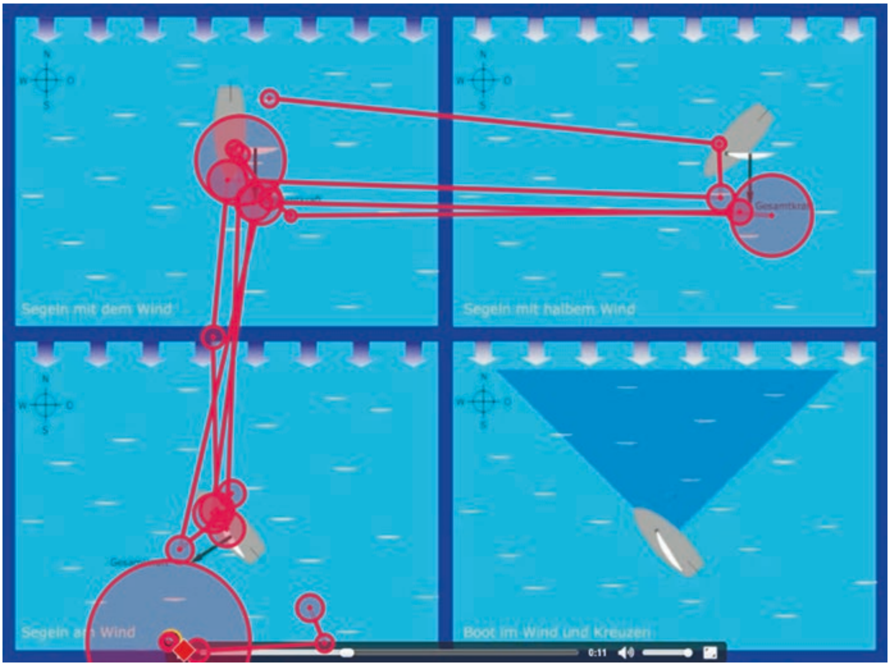

Fig. 3.8 A scan path that visualizes a student's eye movements of the past 10 s. *Larger circles* indicate longer fixation times

Table 3.2 The average frequencies (*M*) and standard deviations (*SD*) of the saccades within the areas of interest (values located on the principal diagonal) and the transitions between the areas of interest (values located above and below the principle diagonal)

		Running		Broad reach		Close hauled	
Group	AOI	*M*	*SD*	*M*	*SD*	*M*	*SD*
Sequential	Running	12.9	7.8	0	0	0	0
($n = 8$)	Broad reach	0	0	58.5	23.9	0.1	0.4
	Close hauled	0.1	0.4	0	0	66.4	22.4
Simultaneous	Running	9.8	15.6	2.0	2.1	2.0	2.4
($n = 8$)	Broad reach	1.6	2.1	18.4	11.7	1.8	1.7
	Close hauled	1.9	2.1	0.9	1.1	31.6	21.3

However, the sequential group ($M = 0.25$, $SD = 0.46$) exhibited significantly fewer transitions between the areas of interest than the simultaneous group ($M = 10.1$, $SD = 7.4$; t-test for independent groups with inhomogeneous variances, $t(7.1) = -3.78$, $p < 0.01$; $d = 1.88$). Conversely, the sequential group ($M = 137.8$, $SD = 43.2$) exhibited significantly more saccades within the different areas of interest than the simultaneous group ($M = 59.8$, $SD = 29.0$; $t(14) = 4.24$, $p < 0.01$; $d = 2.12$). Furthermore, the sequential group showed just one transition between the areas of interest in either direction ($M = 0.13$ and $SD = 0.35$ for transitions in one direction; $M = 0.13$

and $SD = 0.35$ for transitions in the opposite direction). In contrast, the simultaneous group showed several transitions between the areas of interest in both directions ($M = 5.8$ and $SD = 4.5$ for transitions in one direction; $M = 4.4$ and $SD = 3.0$ for transitions in the opposite direction).

Both groups of students possessed very little prior knowledge about the mechanisms underlying sailing (sequential group $M = 0.12$ (1.94%), $SD = 0.36$; simultaneous group $M = 0.07$ (1.11%), $SD = 0.25$). The difference between the sequential group and the simultaneous group in prior knowledge was not significant ($t(58) = 0.61$, *n.s.*). Furthermore, prior knowledge did not significantly correlate with the performance on the posttest ($r = 0.08$, *n.s.*). Therefore, prior knowledge was not considered any further. An analysis of the posttest items revealed an acceptable overall reliability (Cronbach's $\alpha = 0.76$). On the posttest, the simultaneous group performed significantly better than the sequential group (simultaneous group $M = 47.40$ (69.79%), $SD = 9.91$; sequential group $M = 42.10$ (61.91%), $SD = 8.62$; $t(58) = 2.20$, $p < 0.05$; Cohen's $d = 0.57$).

3.5 Discussion

The study reported in this chapter compared the educational effectiveness of the sequential and simultaneous presentation of animation episodes. It yielded three main results. First, the simultaneous presentation resulted in significantly more visual transitions between the episodes than the sequential presentation. Second, the simultaneous presentation lead to significantly more bi-directional visual transitions between the episodes than the sequential presentation. Third, the learning of higher-order relationships was significantly better from the simultaneously presented episodes than from the sequentially presented episodes.

The first two results were consistently found at two levels of detail: (1) the broad scale areas of interest that covered the complete sailing courses and (2) the finer grained areas of interest that covered only the yacht's hull, the sail, and the different forces. These results likely reflect the different affordances that simultaneous and sequential presentations of animated episodes offer to learners. While the simultaneous presentation invites learners to shift their visual attention back and forth between episodes, the sequential presentation suggests that the episodes be processed one after the other. Nevertheless, even with simultaneously presented episodes, uni-directional transitions occurred slightly more often than bi-directional transitions. This tendency may reflect the standard "reading order" from left to right and from top to bottom. The arrangement of the four sailing episodes is consistent with this possibility (cf. Fig. 3.5). Regarding the effects of different presentation formats on learning from pictorial representations, the present results have similarities with those from Lowe, Schnotz, and Rasch (2011). They found that variations in the spatiotemporal arrangement of a set of pictures portraying kangaroo locomotion affected the learners' performance on a sequencing task. The arrangement that provided learners with more affordances for comparing and contrasting important relationships between the kangaroo's body parts resulted in the best performance.

Although the first two results do not directly verify that learners compared the simultaneously presented episodes, the third result suggests that they went beyond a mere mechanistic shifting of their visual attention between episodes. In light of all three results, it appears plausible that learners actively compared and contrasted the episodes in an effort to identify higher-order relationships of the animated subject matter. However, it would be pedagogically unwise to conclude from these results that learners should be instructed to simply shift their visual attention as often as possible between simultaneously presented episodes. According to the APM, it is the comparisons and contrasts made between co-present episodes in order to establish meaningful relationships that are crucial here – the repeated shifts of visual attention are merely perceptual indicators of this deeper processing. Furthermore, the APM also suggests that successful learning from simultaneously as well as sequentially presented episodes requires both within-episode and between-episode interrogation. Without both, it would be difficult for the learner to construct the hierarchical knowledge structure that characterizes a well-developed mental model.

Furthermore, although the simultaneous presentation of animated episodes makes the display much more complex and provides considerably more information to the learners, it did not negatively affect learning as might be expected from the perspective of theoretical frameworks such as the Cognitive Load Theory (e.g., Ayres & Sweller, 2014; van Gog, Paas, & Sweller, 2010). In fact, quite the opposite occurred; it seems that learners are able to regulate their interrogation of an animation in order to avoid being overwhelmed. Perhaps a more sophisticated view of juvenile and adult learners is required in terms of their ability to adapt to complex information environments, for instance, on the basis of perceptual as well as cognitive techniques and strategies (cf. Ploetzner, 2016; Ploetzner, Lowe, & Schlag, 2013; Ploetzner & Schlag, 2013; Kombartzky, Ploetzner, Schlag, & Metz, 2010; see also Ploetzner & Breyer, 2017, this volume). This possibility fits well with the theoretical framework provided by the APM. From this perspective, an animation design that contains deliberate spatiotemporal manipulation of the referent subject matter does not necessarily prejudice learning simply because it results in a more 'difficult' display. Rather, the key issue is what affordances for task-appropriate processing are made available to learners as a result of that manipulation. In the case of converting sequentially occurring episodes into a simultaneous format, it appears that the benefits of being able to carry out the comparisons and contrasts necessary to establish higher-order relationships outweigh the possible costs associated with a more complex and information-rich display.

The induction of higher-order relationships relies on the identification of regularities in the learning material (cf. Holland et al., 1986; Klauer & Leutner, 2012). If the learning material is an expository animation that is not accompanied by verbal explanations, this implies that more than just one instance of a dynamic process needs to be visualized because a single instance of a process does not reveal the process's variability. As a consequence, it is impossible for the learner to identify regularities in the animated subject matter. If multiple instances of a dynamic process are to be displayed to the learner, they can be presented sequentially, simultaneously, or as a combination of both. For instance, the four sailing courses could be presented to the learner as a sequence of several simultaneous presentations with each presentation showing two animation episodes next to each other: initially running and broad reach, then broad reach and close hauled (see Fig. 3.3), and finally close hauled and tacking. Because the results of the study reported in this chapter suggest that the simultaneous presentation of animation episodes affords learners to engage in compare and contrast processes and – as a consequence of this engagement – facilitates the induction of higher-order relationships, a combination of sequential and simultaneous presentations might be especially favorable if a larger number of animation episodes are to be displayed.

In multimedia learning environments, the induction of higher-order relationships does not commonly rely on learning from animation but rather on learning from simulation. While animations merely imitate dynamic processes by presenting fixed sequences of pre-manufactured images, simulations computationally model dynamic processes by making use of formal modeling techniques (cf. Plass & Schwartz, 2014; Ploetzner & Lowe, 2012). Simulations are frequently employed in discovery learning (de Jong & Lazonder, 2014), whereby the learner repeatedly modifies the values of parameters that the simulation offers to the learner via the user interface. By applying the underlying model to the chosen parameter values, the simulation generates symbolic or pictorial representations that describe or visualize the consequences of these modifications. Thereafter, the learner interrogates the generated representations in an attempt to discover regularities. Thus, in contrast to learning from animation, when learning from simulation it is not the designer, but rather the learner who takes responsibility for deciding which instances of a dynamic process are visualized and in which order. Educational research, however, has convincingly demonstrated that discovery learning from simulation poses manifold challenges to learners and therefore requires extensive guidance (cf. Clark, Yates, Early, & Moulton, 2011; de Jong & Lazonder, 2014; de Jong & van Joolingen, 1998). This is especially true if the learners lack the methodological skills for appropriately organizing the discovery process.

When learners do not possess the methodological skills needed to learn effectively from simulation, then learning from multiple animation episodes might be a more promising alternative, particularly if related episodes are presented simultaneously. As in learning from simulation, learning from multiple animation episodes still requires the learner to systematically interrogate the different episodes in order to identify regularities within, as well as across, episodes. In contrast to learning from simulation, however, learners are no longer required to produce sufficiently informative episodes by themselves. Instead, the animation designer supports the learner by providing episodes that cover variability and constancy in the animated subject matter such that the induction of the relevant relationships becomes not only feasible but also realistic.

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