Instructional Science (2026) 54:60
https://doi.org/10.1007/s11251-026-09812-4

ORIGINAL RESEARCH

Pointing task to manage apprehension in dynamic visualization

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Received: 18 November 2024 / Accepted: 15 June 2026

Abstract

Dynamic visualization (i.e., animation; video) is often used to improve comprehension of complex materials. This is why it is crucial to facilitate apprehension of dynamic visualization so learners can more easily elaborate a coherent mental representation. In two experiments, we investigated signaling with a pointing task while viewing a video to facilitate apprehension of a dynamic visualization and thus comprehension. Experiment 1 had 78 participants; Experiment 2 had 85 participants. In both experiments, we measured participants' visuospatial abilities. In both experiments, participants learned about different canine gaits from videos. In Experiment 1, we compared verbal instructions with a pointing task. In Experiment 2, we compared a pointing task with rotation with a pointing task without rotation. We also measured cognitive load. Both experiments showed a positive effect of instructions and pointing tasks (with and without rotation) during video comprehension. Experiment 1 showed a benefit of signaling only for easily apprehensible video and, in contrast, Experiment 2 indicated that pointing tasks were effective regardless of the gait being learned. Our results suggest that a pointing task is not necessarily more useful than instructions alone—learners could misuse the pointing task; also, the pointing task could be effective when the device allows an appropriate use of this task. Another explanation is that learners may have been cognitively fatigued during the first experiment. In this way, signaling could be effective for dynamic visualizations when learners have all their cognitive resources available.

Keywords Comprehension · Dynamic visualization · Pointing · Signaling · Cognitive load

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Published online: 07 July 2026

Introduction

The use of dynamic visualizations, including animations and videos, has increased substantially in educational settings, with the objective of enhancing the comprehension of complex, dynamic content by learners. Domains involving continuous motion, multiple interacting components, and subtle temporal relations that must be integrated over time pose particular instructional challenges. In such cases, the quality of instructional design is critical to ensure that learners can effectively process the information conveyed by dynamic visualizations and construct coherent mental models. Animal locomotion—and canine gaits in particular—constitutes a relevant and challenging domain in this respect. Despite frequent exposure to animals in motion, accurately understanding and explaining gait patterns remains difficult, even for domain experts (Horvath et al., 2009). Misinterpretations of limb coordination, posture, and weight transfer are common and can lead to errors, such as the misdiagnosis of lameness. These difficulties are further compounded by the diversity of gaits, each characterized by distinct biomechanical properties. From an instructional design perspective, this domain provides a meaningful test case for examining how dynamic visualizations can support the learning of complex visuospatial content by making critical features of motion explicit over time.

Dynamic visualizations for learning

Dynamic visualizations in the form of animations (computer generated) or videos are now integral parts of most training courses and are often integrated into multimedia learning materials. We define *dynamic visualizations* as external representations of graphics structures that change over time (Ploetzner & Lowe, 2004) and for which the user can either control the sequence scrolling or cannot control it (i.e., when the sequence is preestablished and the scrolling is thus automatic). The advantage of dynamic visualizations compared to static representations is that they can depict the continuous spatial and temporal evolution of a dynamic process (de Koning et al., 2007; Wagner & Schnotz, 2017). Thus, perceptions of movements should be more effective when a multimedia task includes dynamic visualizations. Such representations can support the construction of an internal mental representation by making successive states of a process explicitly visible, thereby improving comprehension and learning, particularly for content with strong visuospatial components, such as mechanical devices or biological processes. Moreover, it is commonly accepted that dynamic visualization induces higher motivation in learners during complex learning tasks.

Despite the potential, research investigating the learning effectiveness of dynamic visualizations has yielded mixed results (Berney & Bétrancourt, 2016; Höffler & Leutner, 2007; Tversky et al., 2002). Bétrancourt and Tversky (2000), in a first review of the role of animations in comprehension, found contradictory results. Thus, animations, compared with static pictures, do not always prove positive for learning (Castro-Alonso et al., 2014). To analyze more precisely the role of animation in learning, three meta-analyses which compared dynamic visualizations with static illustrations were conducted since 2007. All meta-analyses revealed a small overall effect size in favor of dynamic visualizations, $d = 0.37$ (Höffler & Leutner, 2007), $g = 0.226$ (Berney & Bétrancourt, 2016), and $g = 0.23$ (Castro-Alonso et al., 2019). A reanalysis of Berney and Bétrancourt's study by Ploetzner et al. (2020) used only animations and not dynamic visualizations such as videos, slide shows, and simulations and revealed a small effect size in favor of animations ($g=0.287$). Nevertheless, in this synthesis the authors considered the spatiotemporal changes as a new moderator. The results indicated that animations were more effective than static illustrations, in particular when the contents induced a strong velocity level, with an effect size of $g=0.647$.

Why dynamic visualizations could be ineffective in learning

The results in the extant literature indicate that, in spite of a small benefit for learning, dynamic visualizations can be difficult to process and a source of misunderstanding, in particular for complex and unfamiliar materials. Such difficulties are both perceptual and attentional: perceptual because the speed of dynamic visualization and the simultaneity of movements can be inappropriate, and thus unhelpful, to the human cognitive system, and attentional because novices tend to focus their attention on components that are perceptually salient but not necessarily relevant for comprehension (Boucheix & Lowe, 2010; Lowe, 2004). Because of the limited capacity of attentional and cognitive resources (Baddeley, 1992; Cowan, 2005; Sweller et al., 2011), these sources of difficulties can lead to cognitive overload. However, cognitive load theory might provide some answers. According to this well-known instructional theory, three categories of cognitive load are articulated which depend on the limited capacity of the working memory: (a) extraneous, (b) intrinsic, and (c) germane (Sweller et al., 2011). *Extraneous cognitive load* is due to instructional and design factors; *intrinsic cognitive load* refers to the content of the display that the learner must process; and *germane cognitive load* refers to the effort needed to learn and corresponds to the working memory resources allocated to process intrinsic factors. According to cognitive load theory, levels of both intrinsic and extraneous load depend on *element interactivity*. Element interactivity refers to the number of elements a learner needs to process in their working memory simultaneously in order to understand or solve a task. The higher this interactivity (i.e., the more numerous and interdependent the elements), the greater the cognitive load (Sweller, 1994). Still, a great number of interactive features characterized by complex dynamic visualizations can generate an important intrinsic and extraneous cognitive load, disturbing the elaboration of dynamic mental representation (Castro-Alonso et al., 2014). In acknowledgment of these difficulties, Bétrancourt (2005) specified that a good animation must be apprehensible such that the learner can create a coherent mental representation. Thus, learners should directly perceive and apprehend the external characteristics (i.e., the structure and content) of a dynamic visualization (Tversky et al., 2002). In this way, a dynamic visualization should not include additional cosmetic features.

Individual differences could be another source of difficulty in dynamic visualization processing. Learners with low spatial abilities and without prior knowledge of the task at hand could encounter difficulties to know what, when, and where to look (Lowe, 2008) and to thus extract the relevant information, allowing good comprehension of the phenomenon. In line with the ability-as-enhancer hypothesis, Kühl et al. (2022) argued that learners with very low spatial ability did not benefit from an optimized dynamic visualization design due to a lack of cognitive resources. In contrast, according to the ability-as-compensator hypothesis, learners with high spatial ability could compensate for a suboptimal design and could learn well.

How one learns from a dynamic visualization

Of all the theoretical models that explain how learners construct a mental representation from a text or image, only one pertains to the construction of a mental model from a dynamic visualization and, more particularly, from an animation. The *animation processing model*, developed by Lowe and Boucheix (2008, 2012, 2017), focuses on the data-driven and knowledge-driven processes in a mental model construction. This model describes five phases of animation processing. In these phases, the learner decomposes dynamic information and its products to construct a flexible, high-quality mental model of the animated subject matter.

How a dynamic visualization can facilitate learning

Lowe et al. (2022) considered three ways to improve the effectiveness of animations during learning. These three ways are also compatible with learning from dynamic visualization displays. The first way is to allow the user to control the speed of the dynamic visualization. In this study we did not dwell on this path but rather on the other two. The second way is to introduce minor modifications in the dynamic visualization to facilitate the apprehension of the essential elements for comprehension. Lowe et al. identified two types of modifications investigated by researchers: (a) cueing (signaling) and (b) segmentation. In this study we focused our investigation only on cueing. The third and last way is to stimulate ancillary activities of learners while studying a dynamic visualization.

Attentional guidance

Cues can help learners focus their attention on the important elements of dynamic visualization when these elements are not salient; thus, learners can be helped to decompose a dynamic visualization in a meaningful way. Often, the cueing principle, or signaling principle, indicates that learners learn best when instructional materials incorporate cues to highlight essential elements or relationships among elements (Mayer, 2021; Schneider et al., 2018). According to Mayer (2021) and Van Gog (2022), signaling within pictures or dynamic visualizations can take many visual forms, such as pointing gestures, arrows, distinctive colors, flashing, spotlights, graphic organizers, and a mix of different forms. In other words, cueing in pictures or dynamic visualizations would involve minor display modifications.

Since 2016, researchers have conducted three meta-analyses to specify the signaling effect. Two meta-analyses revealed a small to medium positive effect size of cues on learning. The first meta-analysis, conducted by Richter et al. (2016), focused on cues that highlight the relationship between text and pictures, revealed a small positive effect (Cohen, 1988) of signaling (r = .017) moderated by prior knowledge. The second meta-analysis, conducted by Schneider et al. (2018), revealed a small to medium positive effect (Cohen, 1988) of signaling on retention ($g+=0.53$) and on transfer ($g+=0.33$). In this second meta-analysis, the researchers included different multimedia material, including animated pictures. Finally, in the third meta-analysis, conducted by Alpizar et al. (2020), the results showed a medium positive effect (Cohen, 1988) of the presence of cues in multimedia material, which might include dynamic visualizations, on learning ($d=0.43$).

Focusing more specifically on complex animations, there is a consensus that attentional cues frequently used in static visualizations can be ineffective for dynamic visualizations, as well (de Koning et al. 2009, 2010a, 2010b, 2011; Richter et al., 2016). The salient characteristics of attentional guidance compete with the characteristics of the dynamic visualization. Indeed, attentional cues for dynamic visualization should be specific and compatible with the time frame of the visualization.

In this way, one might also consider another type of effective signaling that is not visual but verbal, in the form of instructions or annotations (Albus et al., 2021; Schneider & Boucheix, 2008). The result will be to guide learners' attention to relevant information without making any changes to the display. Schneider and Boucheix (2008) tested the specific attention orientation effect with particular tasks induced by verbal instructions on the comprehension of a three-pulley system (Hegarty & Just, 1993). The results showed a positive effect of verbal instructions. Comprehension of the mechanism was better when learners were oriented to the processing of system functions than when there was no orientation or when the orientation focused on the configuration of the system. Appropriate instructions could facilitate the integration of the components and of their movements in accordance with the causal chain. Schneider and Boucheix (2007) specified that this type of attentional guidance could be effective, contrary to graphic attentional guidance as arrows, which can be a source of processing difficulties for learners with low visuospatial abilities. More recently, Albus et al. (2021) demonstrated a beneficial effect of text annotations on learning outcomes in recall and on germane cognitive load learning in a virtual reality environment about seawater desalination. These various results lead us to believe that the addition of verbal cueing may be quite appropriate to support learning in complex environments, including dynamic visualizations.

Ancillary activities

An ancillary activity is one that learners perform during learning to facilitate the processing of dynamic visualizations without altering them. Research has focused on generative drawing, gestures, or manipulation of a real physical object relating to the dynamic content of the visualization (Fiorella, 2022; Leutner & Schmeck, 2022). These studies showed contradictory results because these activities could interfere with learning activities because of a split of attentional resources (Lowe et al., 2022). Other ancillary activities should be interesting regarding pointing or tracing during learning. The particularity of these tasks makes it difficult to study with dynamic animations but easier with traditional multimedia supports. Signaling reduces visual search and decreases extraneous load; also, Tang et al. (2019) stated that pointing and tracing could be considered a form of "self-signaling" and could reduce extraneous cognitive load but not intrinsic load. Ginns and King (2021) showed a benefit of a pointing task and tracing during learning of the life cycle of stars on measures of knowledge retention and transfer. Participants also reported a lower extraneous cognitive load. Zhang et al. (2022) studied the effect of finger pointing on learning, focusing on split attention to biological content—the structure and function of the nephron. Participants who used a pointing task showed better comprehension performance. Finger pointing could be a good way to manage the split-attention examples. However, it is challenging to replicate finger-pointing behavior in dynamic animations on a computer screen. Such gestures may obscure or interfere with the intended dynamic aspects that support learning. Granted, we can hypothesize that performing a pointing task on an external medium (e.g., static picture, overlay, or position of crosses in a grid according to a defined pattern) might help direct learners' attention to relevant information within the animation. This could help manage extraneous cognitive load and support the construction of an effective mental representation of content.

Research questions and hypotheses

This study examined two methods for building coherent mental models of dog gaits from videos. The first way was to use attentional guidance with verbal instructions to focus attention on the relevant information necessary for good comprehension. The second way was to use an ancillary activity, a pointing task with verbal instructions during the visualization of complex movements on the video, in order to enhance the effect of verbal instructions. It was challenging to use a pointing task as an ancillary activity in a learning context with dynamic visualizations because the characteristics of our experimental material required learners to perform the task on a paper grid beside the screen rather than on the screen itself. We used this format because, in real-world educational contexts, learners may not always have access to interactive digital tools that allow on-screen annotation or interaction. Our goal was to design an activity reflecting a simple, low-tech strategy learners could apply independently, regardless of available technology (e.g., when watching educational videos at home or in resource-limited classrooms). We acknowledge that placing the pointing task beside the video creates a split-attention demand that could interfere with processing. However, we saw this as an opportunity to test whether learners can benefit from strategies related to the pointing, even under suboptimal conditions. This mirrors many real-world learning environments where perfect integration of materials is not feasible. Additionally, placing the pointing task on the screen next to the video could reduce split attention but would require modifying the learning environment. Our goal was not to create an ideal, optimized interface but rather to assess the practical effectiveness of a simple instructional intervention perhaps broadly applicable.

Experiment 1

Our aim in Experiment 1 was to study the effect of two different types of attentional guidance during comprehension of a dog's gaits presented on slow-motion videos. The demands that dog gaits place on learners observing dynamic visualizations differ. In the present study, gait difficulty is defined as the extent to which the temporal sequence and coordination of limb movements can be accurately perceived and mentally represented from a dynamic visualization. Due to its relatively slow speed and symmetrical, regular temporal pattern, in which the left and right limbs follow the same sequence of movements, the walk was considered the easiest gait to comprehend. In contrast, although the trot is also symmetrical, it was considered more difficult because of its faster speed and the simultaneous movement of diagonal pairs of limbs. The canter was considered the most difficult gait because it is both fast and asymmetrical, with different movement sequences and timings for the left and right limbs. Consequently, differences in comprehension performance were expected as a function of these gait characteristics. The three experimental conditions included a control condition without signaling (Condition 1), signaling with verbal instructions (Condition 2), and signaling with verbal instructions and a pointing task (Condition 3).

Based on previous studies of verbal instructions and pointing in learning activities from animations or multimedia displays, we formulated three hypotheses:

Hypothesis 1 • Participants in the pointing task condition should have a better comprehension score than participants in the verbal instruction condition, who should have a better comprehension score than participants in a control condition.

Hypothesis 2 • The comprehension score should be better for the easiest gaits to apprehend.

Hypothesis 3 • The pointing task and verbal instructions should be effective for the most difficult gaits to apprehend.

Methods

Participants

We performed an a priori power analysis to estimate the necessary sample size. As mentioned before, many meta-analyses of studies of the effects of signaling on learning have reported a medium effect size (Alpizar et al., 2020; Mayer, 2017; Richter et al., 2016; Schneider et al., 2018). Sample size was estimated with a medium effect size $f = 0.25$, with an alpha = 0.05 and a 1 - beta = 0.95, with a repeated-measures design, within–between interaction, and three groups. The total sample size needed was 54 (G*Power Version 3.1; Faul et al., 2009).

In this first experiment, 78 undergraduate students (72 females, six males) from the University of Paris Nanterre participated. Their mean age was 19.4 years ($SD = 2.00$). Participants attended a compulsory experimental psychology course that gave experiment credits. They had to sign a consent form in which it was specified that they could withdraw their consent at any time during the study and/or they could refuse the processing of their data. None of the participants selected had specific prior knowledge about dogs' gaits.

Materials

Four slow-motion movies in which an Appenzeller dog ran at different paces, on treadmills, were presented on a computer screen. Each video was recorded at 500 frames per second and had a total duration of 1 min. Participants watched each video only once and were not given any control over it. The videos used were from the work "Dogs in Motion" by Fischer and Lilje (2014). The four different gaits presented were amble, walk, trot, and canter and their directions were from left to right on the video. In the amble, both paws on the same side of the body land on the ground at approximately the same time. We used amble videos for training because this pace was easier to apprehend than the three others gaits because the limbs of one side of the body do the same as the limbs on the other side, although not simultaneously (Fischer & Lilje, 2014). In the experimental conditions we used the three other videos (Fig. 1), which were more difficult to apprehend than the amble (for more details, see Appendix).

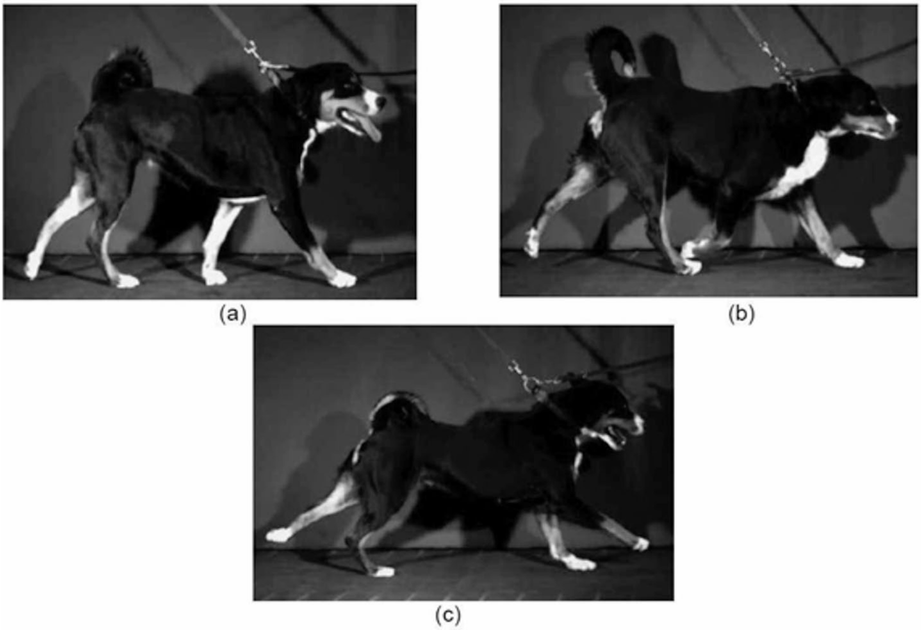


Fig. 1 Video Screenshots of Different Gaits of the Appenzeller Dog. Note. Panel (**a**): walk. Panel (**b**): trot. Panel (**c**): canter

Measures of comprehension

After viewing each video, participants completed a comprehension test designed to assess the quality of their mental representation of the observed gait. The questionnaire consisted of nine items and included multiple-choice questions, open-ended responses, image organization tasks, and grid-completion. Each correct answer, correctly positioned image, or correctly completed grid cell was awarded one point. Because the maximum attainable score differed across gaits (19 points for walk, 18 for trot, and 22 for canter), raw scores were converted into percentages of correct responses to ensure comparability. For each gait, a global comprehension score was calculated by aggregating performance across all questionnaire items.

Here is an example of a multiple-choice question: "In this gait, a step is characterized by the fact that one or more legs rise or fall. How many steps would you break this gait down into? Tick the right answer 2, 4, 6, 8, 10, or 12." For each gait, the open-ended question was "How would you describe this gait?". For the purpose of the study, a scale was established with 7 points allocated for walk, 6 points for trot, and 8 points for canter. The open-ended questions were scored by two independent raters. In instances of disagreement regarding the allocation of scores, the raters engaged in deliberations until a consensus was achieved, with the guidance of a third judge, who was also a certified canine judge from the French Kennel Club.

Internal consistency estimates were as follows: $\omega = 0.49$ for walk, $\omega = 0.45$ for trot, and $\omega = 0.26$ for canter. These values likely reflect the heterogeneous nature of the comprehension tests, which were designed to assess complementary aspects of gait understanding through different task formats (multiple-choice questions, open-ended responses, image organization tasks, and grid-completion tasks) rather than a single homogeneous construct.

Measures of spatial ability

The Spatial Relations subtest of the French version of the Differential Aptitude Test (DAT5; Bennett et al., 2002) was used to measure participants' spatial abilities. This subtest measures aptitude for mental rotation abilities to comprehend figures. It is assessed with 30 multiple-choice questions, each presenting four options (McDonald's $\omega = 0.80$). The maximum score is 30. In this first experiment, the DAT5 average is 15 ($SD = 5.26$). It should be noted that the representative sample used in the French reference normalization of the DAT5 scored an average of 15.2 for males with a baccalaureate degree and 12.3 for females with a baccalaureate degree (Bennett et al., 2002).

Procedure

This experiment was conducted with four participants at a time. The overall procedure involved three stages. During the first stage, after asking for the participants' agreement to take part in the study, we measured their spatial abilities to identify those with high and low spatial abilities. During the second stage, the participants were presented with the training video (amble) and the three other videos of the different gaits on a computer screen. Their task was to understand the gaits by studying the movements of the different parts of the body that play a role in the gaits in order to answer comprehension questions.

Two specific tasks were designed to help the participants elaborate the mental model. In the first task, their attention was focused on the dog's limbs when they touched the ground, the back, the head, and the tail of the dog (verbal instructions). In the second task, in addition to receiving verbal instructions, they drew a cross to represent dog legs on the ground, on a paper grid for each step of the pace (pointing task) while viewing the video. On this occasion, the subjects had eight boxes to fill in, but they did not have to use them all. The last condition was a control condition with no specific task. The subject was simply asked to understand the pace. Participants were randomly assigned to one of three conditions, and the order of the paces was counterbalanced. In the last stage, participants completed a booklet of comprehension question tests after each video.

Results

Statistical analyses were conducted with JAMOVI 2.2.5.0, with the GAMLj package (Gallucci, 2019). Fixed effects in mixed-effects models were tested using marginal F tests, with degrees of freedom approximated using a Satterthwaite method (Satterthwaite, 1946; Kuznetsova et al., 2017). Because partial eta squared is not strictly defined for mixed-effects models, an approximate ηp^2 was derived from the marginal F statistics and their associated degrees of freedom.

Comprehension score

Descriptive statistics for comprehension scores across signaling condition and gait are reported in Table 1. A mixed-effects model was conducted on the global comprehension score, with signaling condition and gait as fixed effects, visuospatial abilities as a covariate, and subjects as random effects.

Effect of signaling condition (Hypothesis 1).

The mixed-effects model revealed no main effect of signaling, $F(2, 72) = 0.54$, $p = .583$, $\eta p^2 \approx 0.02$. Therefore, contrary to Hypothesis 1, there was no significant difference in comprehension performance among the pointing task, verbal instruction, and control conditions when averaged across gaits.

Effect of gait difficulty (Hypothesis 2).

Consistent with this hypothesis, the mixed-effects model revealed a significant main effect of gait, $F(2, 148) = 50.43$, $p < .001$, $\eta p^2 \approx 0.41$. Post hoc comparisons with Holm correction showed that participants performed better for walk than trot ($p_{Holm} < 0.001$), and better for trot than canter ($p_{Holm} < 0.001$), indicating a clear gradient of comprehension in relation to gait difficulty.

Effectiveness of signaling for the most difficulty gait (Hypothesis 3).

The mixed-effects model revealed a significant interaction between gait and signaling, $F(4, 148) = 2.47$, $p = .047$, $\eta p^2 \approx 0.06$, indicating that the effect of signaling varied as a function of gait difficulty.

To test Hypothesis 3 directly, post hoc comparisons with Holm correction were conducted for the most difficult gait (canter). These analyses showed that comprehension performance for the canter condition did not differ significantly between the pointing task, verbal instruction, and control conditions (all $p_{Holm} > 0.05$). Similarly, no significant differences between signaling conditions were observed for the walk and trot gaits (all $p_{Holm} > 0.05$). Therefore, neither the pointing task nor verbal instructions led to a significant improvement in comprehension for the most difficult gait. Accordingly, Hypothesis 3 was not supported.

Additional post hoc analyses examining differences within signaling conditions showed that effects were limited to the easiest gait (walk). In the verbal instruction condition, comprehension performance was higher for walk than for trot ($p_{Holm} = 0.040$) and canter (p_{Holm}

Table 1 Mean Percentage Scores on the Global Comprehension Measure for Three Gaits as a Function of Signaling

Variable	M (SD)		
	Walk (n=78)	Trot (n=78)	Canter (n=78)
Control (N=26)	44.81 (13.09)	38.78 (9.54)	27.97 (11.11)
Verbal instructions (N=26)	53.54 (16.58)	38.46 (14.33)	28.23 (13.77)
Pointing task (N=26)	53.24 (16.58)	32.26 (15.01)	27.71 (8.95)

< 0.001), and higher for trot than canter (p_{Holm} = 0.017). In the pointing task condition, comprehension performance was higher for walk than for trot and canter (both p_{Holm} < 0.001).

Additional result: role of visuospatial ability.

Across analyses, visuospatial ability was significantly associated with comprehension performance. Visuospatial ability scores were positively correlated with comprehension scores for walk ($r = .31$, $p = .006$), trot ($r = .37$, $p < .001$), and canter ($r = .34$, $p = .003$). Moreover, the mixed-effects model showed a significant main effect of visuospatial ability on global comprehension scores, favoring learners with strong abilities, $F(1, 72) = 17.52$, $p < .001$, $\eta p^2 \approx 0.20$.

Discussion

The first experiment examined whether attentional guidance, implemented through verbal instructions or a pointing task, facilitates learners' comprehension of canine gaits presented in slow-motion videos, and whether such guidance is particularly beneficial for more difficult gaits.

In contrast to what we expected in Hypothesis 1, the combination of verbal instructions with a pointing task did not result in enhanced comprehension when compared to verbal instructions alone or in the absence of guidance. Adding an ancillary activity to verbal instructions did not lead to a better elaboration of a mental representation. One potential explanation for this phenomenon is that learners may not have used the pointing task in an optimal way. It is noteworthy that the pointing task did not compromise comprehension relative to verbal instructions alone, indicating that it did not induce adverse split-attention effects.

In accordance with Hypothesis 2, comprehension performance decreased as gait difficulty increased. Walk was the most easily apprehended gait, followed by trot and then canter, suggesting that the inherent characteristics of the gaits give rise to distinct levels of difficulty.

The data analysis did not support the conclusions of Hypothesis 3. The presence of verbal instructions with or without pointing task did not have a significant impact on comprehension for the most complex gait, designated as the canter. More generally, post hoc analyses revealed no significant differences among signaling conditions for any of the gaits, indicating that neither verbal instructions nor the pointing task led to higher comprehension scores when compared with the control condition.

However, analyses conducted within signaling condition showed that differences across gaits were limited to the easiest gait (walk) and did not extend to more difficult gaits. Specifically, when attentional guidance was provided, comprehension performance was higher for walk than for trot and canter, whereas no such difference between walk and trot was observed in the control condition. This pattern suggests that attentional guidance primarily affected the processing of the most easily apprehended gait rather than facilitating understanding of more complex movements.

Taken together, these findings suggest that signaling may support the comprehension of dynamic visualizations only when the content is sufficiently easy to apprehend. For more complex and fast-moving gaits, such as trot and canter, learners did not benefit from additional instructional cues. This interpretation is consistent with the principle of Cognitive Load Theory (Sweller et al., 2011), which posits that when a dynamic visualization is relatively simple, learners may have sufficient cognitive resources to process attentional guiding and use it to develop a coherent mental model. In contrast, when dynamic visualization is elusive because of too much information to be processed simultaneously with a rapid movement, the resultant high cognitive load may limit the effectiveness of signaling. This is because learners must allocate cognitive resources to understanding the movement itself while concurrently maintaining instructional cues.

Experiment 2

In Experiment 1, we did not find a difference between verbal instruction and a pointing task. Moreover, we found that attentional guidance was effective only for a dynamic visualization that was easy to apprehend and facilitated a mental model elaboration.

The first question we addressed in this experiment was whether it was possible to make verbal instruction with the pointing task more effective. There is a link between the congruence of body posture and the direction of mental rotation (Kessler & Thomson, 2010). An egocentric perspective should provide a better understanding of movement dynamics, as it is aligned with the subject's body because it is more natural. A pointing task with mental rotation that induces a first-perspective alignment could be better than a pointing task without mental rotation, inducing a third-perspective alignment. Having a learner perform a mental rotation, allowing it to be in a perspective aligned with the body, would allow an optimal use of the ancillary activity by simulating the movement with another point of view. This could make it possible to reduce extraneous load as in previous studies in the field of multimedia learning. The second question was if a dynamic visualization induces a high cognitive load (mainly intrinsic cognitive load), then does attentional guidance with a pointing task facilitate the elaboration of a coherent mental model. To answer these questions, we conducted Experiment 2.

The aim of this second experiment was to study the effect of the pointing task on cognitive load. In addition, we tested two different types of pointing tasks during the comprehension of canine gaits, presented on slow-motion videos (the same as in Experiment 1). The three experimental conditions included a control condition without signaling (Condition 1), signaling with instructions and a pointing task with rotation (Condition 2), and signaling with instructions and a pointing task without rotation (Condition 3, as in Experiment 1). Moreover, we measured cognitive load after each video with a French translation of the cognitive load multiscale developed by Klepsch et al. (2017).

For this second experiment, we formulated three hypotheses:

Hypothesis 1 • Participants in the pointing-task-with-rotation condition should have better comprehension scores and should report lower cognitive load than participants in the pointing-task-without-rotation condition, who should have better comprehension scores and lower cognitive load than participants in the control condition.

Hypothesis 2 • Comprehension scores should be higher for the easiest gaits to apprehend.

Hypothesis 3 • The pointing task with rotation should be effective for the more-difficult gaits to apprehend.

Methods

Participants

As in Experiment 1, we estimated the sample size with G*power, with the same input parameters. The total sample size needed was 54.

In this second experiment, 85 undergraduate students (76 females, nine males) from the University of Paris Nanterre participated. Their mean age was 19.19 years (*SD* = 3.35). Participants attended a compulsory experimental psychology course that gave experiment credits. They had to sign a consent form in which it was specified that they could withdraw their consent at any time during the study and/or they could refuse the processing of their data. None of the participants selected had specific prior knowledge about dogs' gaits.

Materials

In this second experiment, we used the same four slow-motion movies used in Experiment 1. We always used the amble movie for the training, and we used the three other movies as experimental conditions.

Measures of comprehension

We used the same questionnaire as in Experiment 1 to measure learner comprehension. As in Experiment 1, internal consistency estimates for the comprehension tests were calculated using McDonald's omega and were as follows: $\omega = 0.43$ for walk, $\omega = 0.35$ for trot, and $\omega = 0.39$ for canter.

Measures of spatial ability

Like in Experiment 1, the Spatial Relations subtest of the French version of the DAT5 was used to measure spatial abilities (McDonald's $\omega = 0.84$). In this second experiment, the DAT5 average was 15.85 (*SD* = 5.83), similar to Experiment 1.

Measures of cognitive load

Cognitive load scale.

We used a cognitive load scale developed by Klepsch et al. (2017). Two items measure intrinsic cognitive load; three items measure germane cognitive load; and three items measure extraneous cognitive load. Each of eight items has to be rated on a 7-point Likert scale (that ranged from *absolutely wrong* to *absolutely right*).

We analyzed the reliability of the scores (*N* = 85) of the questionnaire for each gait. We used Macdonald's ω to measure the scale's internal consistency. We averaged these scores for each cognitive load to control for potential variation related to running order.

The range of value of the ω coefficient for intrinsic load for each experimental condition was 0.56–0.88, with a mean value of 0.78. The range value of the ω coefficient for germane load for each experimental condition was 0.49–0.77, with a mean value of 0.63. Finally, the range of value of the ω coefficient for extraneous load for each experimental condition was 0.50–0.77, with a mean value of 0.65. We considered the values acceptable to analyze the results of the three dimensions of cognitive load (Schmitt, 1996).

Procedure

We conducted the experiment with four participants at a time. The overall procedure involved three stages. During the first stage, after asking for the participants' agreement to take part in the study, we showed them the training video (amble) and the three other videos of the different gaits on a computer screen. Their task was to understand the gaits by studying the movements of the different parts of the body that play a role in the gaits in order to answer comprehension questions.

Two specific tasks were designed to help the learners elaborate the mental model. Also, the first condition was the pointing task condition used in Experiment 1. The learners were meant to focus attention on a different part of the dog's body, and they had to draw a cross to represent the dog's legs on the ground on a paper grid for each step of the gait. As in Experiment 1, the direction of the dog's gait was from left to right on the video, the same as in the grid. Also, the learners were not to make a mental rotation (pointing task, no rotation). In the second condition, the learners' task was the same as in the first condition, but they should make a mental rotation because the direction of the legs was horizontal (from left to right) in the video and vertical for the paper grid where the pointing task was aligned with the participant's body (pointing task with rotation, see Appendix). The last condition was the control condition. It was identical to Experiment 1 in that participants were not given a specific task; they simply had to try to understand the images presented in the video.

The participants were randomly assigned to one of three conditions, and the order of the gaits was counterbalanced. In the second stage, participants answered the French version of the cognitive load scale after each video. In the third stage of the experiment, the subjects were invited to complete a booklet of comprehension questions following the view of each video. In the last stage, when the participants had watched all the videos and answered all the questionnaires, we measured their spatial abilities. In contrast to the first experiment, we measured spatial abilities after the experimental conditions in order not to affect performance on the cognitive load measures.

Results

Correlations between visuospatial abilities, comprehension, and cognitive load measures

Table 2 presents the correlations between visuospatial abilities, comprehension, and the different cognitive load measures.

Correlations between comprehension scores and cognitive load measures showed that the comprehension scores were negatively correlated with Intrinsic Cognitive Load and Extraneous Cognitive Load, but only for the canter. When material was difficult to appre-

Table 2 Correlations Between the Comprehension Scores, the Cognitive Load Measures, and Spatial Relation Scores for Walk, Trot, and Canter

Variable	1	2	3	4	5
Walk					
1. Comprehension	—	−0.02	0.12	0.04	0.22*
2. ICL		—	−0.004	0.61***	0.06
3. GCL			—	−0.04	−0.10
4. ECL				—	−0.02
5. DAT5					—
Trot					—
1. Comprehension	—	−0.16	0.18	−0.15	0.39***
2. ICL		—	−0.03	0.53***	−0.03
3. GCL			—	−0.01	−0.11
4. ECL				—	−0.02
5. DAT5					—
Canter					
1. Comprehension	—	−0.22*	−0.03	−0.26*	0.35**
2. ICL		—	0.05	0.61***	0.01
3. GCL			—	0.06	−0.09
4. ECL				—	−0.14
5. DAT5					—

Note. ICL = Intrinsic Cognitive Load; GCL = Germane Cognitive Load; ECL = Extraneous Cognitive Load; DAT5 = Differential Aptitude Test (5th ed.)

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

Table 3 Mean Percentage Scores on the Comprehension Tasks for Three Gaits as a Function of Pointing Task Condition

Variable	M (SD)		
	Walk (n=85)	Trot (n=85)	Canter (n=85)
Control (N=28)	50.9 (13.2)	40.0 (10.5)	29.2 (11.4)
Pointing task, rotation (N=29)	55.7 (12.2)	44.6 (14.1)	40.2 (12.3)
Pointing task, no rotation (N=28)	55.1 (11.9)	41.6 (13.7)	38.1 (15.1)

hend and was a source of cognitive load, the comprehension performances were poor. There was a positive correlation between comprehension scores and visuospatial ability scores. However, the results did not show any correlations between visuospatial ability scores and cognitive load measures.

Comprehension scores

Table 3 presents the comprehension scores in the three conditions and for the three gaits. A mixed-effects model was conducted on the global comprehension score, with pointing task condition and gait as fixed effects, visuospatial abilities as a covariate, and subjects as random effects.

Effect of pointing task (Hypothesis 1).

In accordance with Hypothesis 1, the mixed-effects model revealed a significant main effect of pointing task on comprehension scores, $F(2, 79.1) = 4.37$, $p = .016$, $\eta p^2 \approx 0.10$.

Participants in both pointing task conditions (with and without rotation) obtained higher comprehension scores than participants in the control condition (Holm-corrected post hoc comparisons indicated significance in both cases, $p_{Holm} = 0.033$). However, no significant difference was observed between the pointing task with rotation and the pointing task without rotation conditions ($p_{Holm} = 0.933$). Thus, while the presence of a pointing task improved comprehension relative to the control condition, the predicted superiority of the rotation condition over the non-rotation condition was not supported.

Effect of gait difficulty (Hypothesis 2).

In accordance with Hypothesis 2, a significant main effect of gait was observed, $F(2, 162.1) = 63.16$, $p < .001$, $\eta p^2 \approx 0.44$. Post hoc comparisons indicated that comprehension scores were higher for walk than for trot ($p_{Holm} < 0.001$) and higher for trot than for canter ($p_{Holm} = 0.001$), demonstrating a clear gradient of performance as a function of gait difficulty.

Effectiveness of pointing task with rotation for the most difficulty gait (Hypothesis 3).

In contrast to the predictions made by Hypothesis 3, the interaction between gait and pointing task was not significant, $F(4, 162.1) = 1.16$, $p = .333$, $\eta p^2 \approx 0.03$. This indicates that the effect of the pointing task on comprehension did not vary as a function of gait difficulty. In other words, although pointing tasks improved comprehension overall relative to the control condition, the rotation component did not provide a specific advantage for more difficult gaits.

Additional result: role of visuospatial ability.

Across analyses, visuospatial ability had a significant effect on comprehension performance, $F(1, 82.3) = 19.62$, $p < .001$, $\eta p^2 \approx 0.19$, indicating that higher spatial ability was associated with better comprehension scores.

Measures of cognitive load

***Intrinsic load*.**

Table 4 presents the intrinsic load scores in the three conditions and for the three gaits. A mixed-effects model was conducted on perceived intrinsic load, including pointing task condition and gait as fixed and subjects as random effects.

Table 4 Mean Scores on the Intrinsic Load Measure for Three Gaits as a Function of Pointing Task Condition

Variable	M (SD)		
	Walk (n=85)	Trot (n=85)	Canter (n=85)
Control (N=28)	3.70 (1.50)	3.98 (1.38)	5.25 (1.08)
Pointing task, rotation (N=29)	3.72 (1.29)	2.71 (1.14)	4.71 (1.68)
Pointing task, no rotation (N=28)	3.18 (1.51)	3.13 (1.32)	4.38 (1.36)

Effect of pointing task (Hypothesis 1).

The analysis revealed a significant main effect of pointing task on perceived intrinsic load, $F(2, 82) = 3.44$, $p = .037$, $\eta p^2 \approx 0.08$. A post hoc test with Holm correction revealed that the perceived intrinsic load was greater in the control condition than in the condition with the pointing task without rotation ($p_{Holm} = 0.045$). No significant difference was observed between the control condition and the pointing task with rotation condition ($p_{Holm} = 0.100$), nor between the pointing task with and without rotation conditions ($p_{Holm} = 0.611$). Thus, while the presence of a pointing task without rotation was associated with reduced perceived intrinsic load compared with the control condition, the expected graded reduction of intrinsic cognitive load across the three conditions was not fully supported.

Effect of gait difficulty (Hypothesis 2).

In accordance with Hypothesis 2, a significant main effect of gait was observed, $F(2, 164) = 60.80$, $p < .001$, $\eta p^2 \approx 0.43$. Post hoc analyses revealed that perceived intrinsic load was higher for the canter than for the walk ($p_{Holm} < 0.001$) and the trot ($p_{Holm} < 0.001$), indicating that gait difficulty was associated with increased intrinsic cognitive load.

Effectiveness of pointing task with rotation for the most difficulty gait (Hypothesis 3).

Results showed a significant interaction of pointing task and gait, $F(4, 164) = 3.81$, $p = .005$, $\eta p^2 \approx 0.09$, but did not support the predicted pattern. Post hoc analyses showed that perceived intrinsic load was higher in the control condition than in the pointing task with rotation condition only for the trot ($p_{Holm} = 0.013$). No significant differences between pointing task conditions were observed for the most difficult gait (canter). Thus, although the effect of pointing task on perceived intrinsic load varied across gaits, the pointing task with rotation did not selectively reduce cognitive load for the most difficult gait.

Germane load.

Table 5 presents the germane load scores in the three conditions and for the three gaits. A mixed-effects model was conducted on perceived germane load, including pointing task condition and gait as fixed and subjects as random effects.

Effect of pointing task (Hypothesis 1).

The analysis did not reveal a significant main effect of pointing task condition on perceived germane load, $F(2, 82) = 0.28$, $p = .754$, $\eta p^2 \approx 0.01$. Perceived germane load did not differ

Table 5 Mean Scores on the Germane Load Measure for Three Gaits as a Function of Pointing Task Condition

Variable	M (SD)		
	Walk ($n=85$)	Trot ($n=85$)	Canter ($n=85$)
Control ($N=28$)	4.68 (0.99)	4.74 (1.11)	4.94 (1.03)
Pointing task, rotation ($N=29$)	4.86 (1.21)	4.68 (1.21)	4.63 (1.14)
Pointing task, no rotation ($N=28$)	4.96 (1.27)	4.75 (1.15)	5.04 (1.21)

Table 6 Mean Scores on the Extraneous Load Measure for Three Gaits as a Function of Pointing Task Condition

Variable	M (SD)		
	Walk (n=85)	Trot (n=85)	Canter (n=85)
Control (N=28)	3.02 (1.23)	3.21 (1.06)	4.05 (1.11)
Pointing task, rotation (N=29)	2.90 (1.20)	3.02 (1.05)	3.32 (1.19)
Pointing task, no rotation (N=28)	2.92 (1.14)	2.77 (1.15)	3.29 (1.27)

between the pointing task with rotation, the pointing task without rotation, and the control conditions.

Effect of gait difficulty (Hypothesis 2).

Results did not support this hypothesis for germane load. No significant main effect of gait was observed, $F(2, 164) = 0.93$, $p = .396$, $\eta p^2 \approx 0.01$, indicating that perceived germane load did not differ across walk, trot, and canter.

Effectiveness of pointing task with rotation for the most difficulty gait (Hypothesis 3).

the interaction between pointing task condition and gait was not significant, $F(4, 164) = 0.10$, $p = .411$, $\eta p^2 \approx 0.02$. This result indicates that the effect of the pointing task on perceived germane load did not vary as a function of gait difficulty. Thus, the pointing task with rotation did not lead to increased germane load for the more difficult gaits.

Extraneous load.

Table 6 presents the extraneous load scores in the three conditions and for the three gaits. A mixed-effects model was conducted on perceived germane load, including pointing task condition and gait as fixed and subjects as random effects.

Effect of pointing task (Hypothesis 1).

The analysis did not reveal a significant main effect of pointing task on perceived extraneous load, $F(2, 82)=1.51$, $p = .228$, $\eta p^2 \approx 0.04$. Perceived extraneous load did not differ significantly among the pointing task with rotation, the pointing task without rotation, and the control conditions. Thus, Hypothesis 1 was not supported with respect to extraneous load.

Effect of gait difficulty (Hypothesis 2).

In accordance with Hypothesis 2, a significant main effect of gait was observed, $F(2, 164)=18.35$, $p < .001$, $\eta p^2 \approx 0.18$. Post hoc comparisons with Holm correction indicated that perceived extraneous load was higher for trot and canter than for walk (both $p_{Holm} < 0.001$), and higher for canter than for trot ($p_{Holm} < 0.001$). This pattern reflects a clear increase in extraneous load as gait difficulty increased.

Effectiveness of pointing task with rotation for the most difficulty gait (Hypothesis 3).

The interaction between pointing task condition and gait was not significant, $F(4, 164) = 2.14$, $p = .079$, $\eta p^2 \approx 0.05$. This result indicates that the effect of the pointing task on perceived extraneous load did not vary as a function of gait difficulty. Therefore, the pointing task with rotation did not selectively reduce extraneous load for the more difficult gaits.

Discussion

In answer to the first question of Experiment 1—whether mental rotation during a pointing task could be a source of lower cognitive load and positively affect comprehension performances due to a first-perspective alignment compared with a pointing task without mental rotation—our results did not support this. Regarding comprehension, no significant differences were observed between the two pointing task conditions; however, both pointing conditions led to higher comprehension performance than the control condition. Unlike in the first experiment in which signaling and, in particular, the pointing task were only effective for the simplest gait, the results of the second experiment revealed a main effect of the two pointing task conditions regardless of gait difficulty.

With respect to intrinsic cognitive load, the control condition was associated with higher perceived load than the pointing task without rotation. In addition, for the trot gait, perceived intrinsic load was higher in the control condition than in the pointing task with rotation. Together, these findings indicate that while mental rotation did not confer an advantage over a pointing task without rotation, the presence of a pointing task was associated with both improved comprehension and reduced intrinsic cognitive load compared with the control condition.

Results suggest that directing attention towards relevant information and engaging participants in a pointing task could promote a more effective analysis of the movement. This strategy could help manage essential processing of our training video by breaking up the continuity of the movement, which is consistent with the segmentation principle (Mayer & Chandler, 2001). Finally, the pointing tasks did not appear to induce extraneous cognitive load due to poor design, which further supports their instructional value.

Another challenging result is that gait showed a significant main effect on extraneous cognitive load. In our opinion, this was not a sensitivity issue of the measure, even if the gaits themselves are the content of the learning task (and not extraneous). Gaits actually have different velocities. The videos reproducing these different velocities have the consequence of impacting the speed of the video itself and therefore inducing a greater extraneous load for the fastest gaits.

General discussion

In two experiments we facilitated the apprehension of a complex dynamic visualization with verbal instructions with or without a pointing task. In the first experiment, we compared two ways to facilitate the elaboration of a mental representation of a dog's gaits from three slow-motion videos. Only one hypothesis (Hypothesis 2) about the effect of the level of complexity of the material was confirmed by our data analyses. Unexpectedly, we did not find differences between the two experimental conditions. The pointing task did not bring any additional benefit to the verbal instructions for learning. Perhaps in this experiment the learners did not use the pointing task optimally during the learning phase. Nevertheless, the pointing task did not disturb the instruction's effect and was not a source of misunderstanding for learners (Hypothesis 1).

Surprisingly, focusing attention on the relevant part of the dynamic visualizations through verbal instructions, with or without a pointing task, helped learners extract essential information only for the most apprehensible gait (walk) but did not improve comprehension for the more complex gaits (Hypothesis 3). As mentioned before, we observed small positive effects of signaling on learning with a dynamic visualization (Alpizar et al., 2020; Schneider et al., 2018), and we observed contradictory results about the pointing task as an ancillary activity in learning with multimedia displays (Lowe et al., 2022). This lack of clarity could be due to the characteristics of the material and its complexity in the different studies. In line with our results, these ways of focusing attention on relevant information during learning with a dynamic visualization to facilitate comprehension can be effective only when the material is not too complex and the learners can use these aids effectively. Therefore, complex dynamic visualizations involve an important intrinsic cognitive load. This overload can lead to difficulties in using the aids provided to learners during learning because of a lack of attentional and cognitive resources.

To clarify our results from the first experiment, we performed a second experiment in which we compared two types of pointing tasks, one without mental rotation, as in Experiment 1, and another with mental rotation, so that the pointing task was aligned with the participant's body. Moreover, we measured cognitive load to test if the effectiveness of attentional guidance depends on the complexity of the material, and if adding an ancillary activity could decrease cognitive load, as has been shown in many studies (Tang et al., 2019; Zhang et al., 2022). Like in Experiment 1, our data analyses revealed unexpected results, and we did not replicate all the main results observed in Experiment 1. Only the effect of the level of complexity of the material was replicated (Hypothesis 2). Unexpectedly, we did not find differences between the pointing task with and without rotation both for comprehension scores and for the cognitive load generated (Hypothesis 1). Engaging in a pointing task from an egocentric perspective that requires mental rotation does not improve learning outcomes from dynamic visualizations.

Finally, against all expectations, our results did not confirm that the pointing task with rotation is more effective for more complex gaits (Hypothesis 3). Thus, the assumption that the effectiveness of attentional guidance and ancillary activities depends on the difficulty of the material is not entirely accurate. Considering the poor performance in Experiment 1 and the change in position of the spatial ability test between Experiments 1 and 2, one plausible explanation is that the participants were negatively affected by the 15-minute test before the experimental conditions were facilitated in Experiment 1. The learners may have experienced cognitive fatigue that decreased the availability of their already-restricted attentional and cognitive resources. Another consequence of this cognitive fatigue was a probable decrease in intrinsic motivation, resulting in a loss of interest in the task on the part of the learners. In Experiment 2, the spatial ability test was administered after the experimental conditions, when participants were in full possession of their resources. The learners could use the pointing tasks effectively to improve their comprehension overall relative to the control condition. Another plausible explanation is that the participants did not make optimal use of the pointing tasks. In fact, a closer look at the protocols revealed that the participants used a low number of grid squares. The ephemera of the videos and the induced split attention undoubtedly proved detrimental to the correct use of this ancillary task. Allowing participants to control the flow of the video by pausing or rewinding could make this task more effective. In this way, participants might complete the pointing task and not lose any information from the dynamic visualization.

Limitations and future research

This study had three principal limitations. The first limitation was the characteristics of the pointing task. The pointing tasks used in the two experiments were dissociated from the experimental material and induced a split-attention effect between the stimulus and the grid. We can solve this by positioning it on a secondary monitor as close as possible to the primary monitor or by using a particularly big monitor that shows both the animation and the pointing task to minimize the split-attention effect. In addition, the fact that the dynamic visualization was not controllable in our two studies meant that the pointing task could be difficult to perform and therefore lacked effectiveness. In future studies, to make the pointing task more effective, one might make the videos controllable with another instruction like "try to fill in as much as you can while watching the video." In this way, it would be relevant to analyze the quality of the pointing task performed by the subjects and relate this to comprehension performance.

The second study limitation was the change of the position of the spatial ability test during the experiment between Experiments 1 and 2. Future research should explore the vague concept of cognitive fatigue or mental fatigue in the use of attentional guidance tools during learning with complex dynamic visualizations.

The third and final limitation was the lack of a French-validated scale to measure cognitive load. We were therefore unable to replicate the results of previous research on extraneous load. The validation of a French scale would provide a reliable measurement tool.

Conclusions

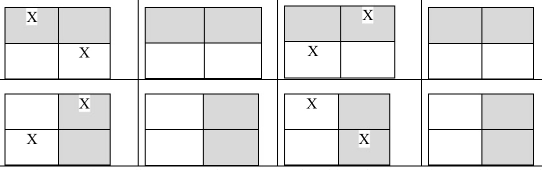
We demonstrated that understanding animals' gaits is a complex task and often a source of errors, even for experts and artists. The use of videos for learning gaits proves to be relevant if the learner is able to extract useful information to develop an adequate mental representation. Also, attentional guidance through verbal instructions accompanied or not by a pointing task proved to be relevant. Nevertheless, the real contribution of a pointing task (as we developed it) remains to be demonstrated. It would be particularly relevant if it can be used correctly by learners (controllable video) and if they would have the necessary cognitive resources available to use it fully (learner not cognitively fatigued) and of course if the learners engage in learning. These will hopefully be subjects of future studies.

Appendix

This appendix consists of pictures of the different steps of each canine gait used in the two experiments from the videos as well as the pointing tasks with (first line underneath the pictures) and without rotation (second line underneath the pictures) and their definitions. To facilitate the comprehension of the pointing task, the gray lines represent the front legs.

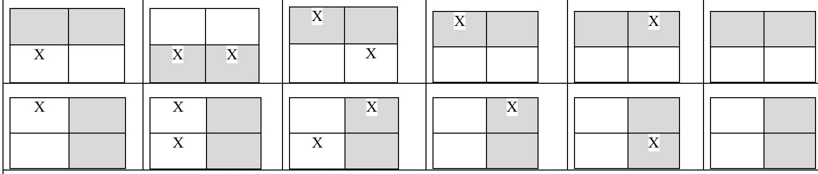
Amble						
	[X][ ] [X][ ]	[ ][X] [ ][X]				
	[X][X] [ ][ ]	[ ][ ] [X][X]				
	In the amble, both paws on the same side of the body land on the ground at approximately the same time.					
Walk						
	[ ][X] [X][X]	[X][X] [X][ ]	[X][ ] [X][X]	[X][X] [ ][X]		
	[X][ ] [X][X]	[X][X] [ ][X]	[X][X] [X][ ]	[ ][X] [X][X]		
	The walk gait is a slow, walking, symmetrical, four-beat gait. During this gait, the dog has, most of the time, three paws on the ground and two paws on the ground for very short times. The dog lifts each leg, one after the other, in the following order: left front leg, right hind leg, right front leg, and left hind leg					

Trot



Trot is faster than walk or slower than canter and is skipped, symmetrical, and has four beats. In this gait, a phase in which the left front leg and right hind leg are placed alternates with a phase in which the right front leg and left hind leg are placed. In this gait, there are two phases of suspension, each of which takes place between the two previously named phases.

Canter



Canter is a fast, jumping, asymmetrical, six-beat gait. In this gait, the dog starts by pressing down with the left hind leg, then follows with the left diagonal biped, then the right front leg. More specifically, canter is characterized by the following phases: left hind leg down, right and left hind legs down, right hind leg and left front leg down, left front leg down, then right front leg down. This last phase is followed by a suspension phase.

Acknowledgements The authors would like to thank the associate editor and the anonymous reviewers for their constructive comments and suggestions, which have helped to improve the clarity and quality of this manuscript. We would also like to thank Jean-Michel Boucheix for his careful proofreading and valuable feedback. We are grateful to Martin Fischer for granting us permission to use his videos in this research. We thank Maréva Vaiho for her help with data collection. Finally, we thank all the participants who made this study possible.

Declarations

Informed consent All participants were of legal age and had to sign a consent form after reading it and the experimenter had verified that they understood that they could withdraw from the experiment at any time.

Competing Interests My coauthors and I do not have any conflict of interest to disclose. The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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