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ARTICLE

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Should learners use their hands for learning? Results from an eye-tracking study

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Abstract
Given the widespread use of touch screen devices, the effect of the users' fingers on information processing and learning is of growing interest. The present study drew on cognitive load theory and embodied cognition perspectives to investigate the effects of pointing and tracing gestures on the surface of a multimedia learning instruction. Learning performance, cognitive load and visual attention were examined in a one-factorial experimental design with the between-subject factor pointing and tracing gestures. The pointing and tracing group were instructed to use their fingers during the learning phase to make connections between corresponding text and picture information, whereas the control group was instructed not to use their hands for learning. The results showed a beneficial effect of pointing and tracing gestures on learning performance, a significant shift in visual attention and deeper processing of information by the pointing and tracing group, but no effect on subjective ratings of cognitive load. Implications for future research and practice are discussed.

KEYWORDS
cognitive load theory, embodied cognition, eye-tracking, tracing gestures

1 | INTRODUCTION

Hand and finger gestures are an important factor for human communication (Krauss, Chen, & Gottesman, 2000) and are, with regard to recent technology, also important for information processing and learning by means of touch screen devices (for a detailed discussion see Agostinho, Ginns, Tindall-Ford, Mavilidi, & Paas, 2016). Several studies have already shown pointing to and/or tracing the index finger against key elements of learning materials facilitates the learning process for school pupils and adults (Agostinho et al., 2015; Ginns, Hu, Byrne, & Bobis, 2016; Ginns & Kydd, 2019; Hu, Ginns, & Bobis, 2014, 2015; Macken & Ginns, 2014; Pouw, Mavilidi, van Gog, & Paas, 2016; Tang, Ginns, & Jacobson, 2019). Reviewing the above body of research, Park, Korbach, Ginns, and Brünken (2019) argued the beneficial effects of finger pointing and tracing gestures can potentially be explained by three prominent and mutually informative theoretical assumptions, all of which are underpinned by embodied cognition perspectives (Foglia & Wilson, 2013; Wilson, 2002). The first assumption is that the focus of visual attention is increased for the processing of information near the hand or the fingers with a beneficial effect of haptic modality on visual attention (Abrams, Davoli, Du, Knapp, & Paull, 2008; Reed, Grubb, & Steele, 2006). A second assumption is about embodied memory patterns (Glenberg, 1997) with an inherent relation between cognitive processing and the bodily states due to interactions with the learning environment and the learning task. Third, cognitive load theory (Choi, van Merriënboer, & Paas, 2014; Paas & Sweller, 2012; Plass, Moreno, & Brünken, 2010) assumes an evolutionary account (Geary, 2008) with a beneficial effect on cognitive load consumption when biologically primary knowledge - including gestures - is used to construct biologically secondary knowledge. To this end, the present study analyses the learners' eye movements in combination with test performance and cognitive load in order to provide a fine-grained analysis of the effects of pointing and tracing gestures on learning performance. We now review each of these perspectives.

1.1 | Visual attention

One explanation for the beneficial effects of hand and finger gesturing is that these gestures affect the visual focus of attention. The hand and the fingers can thereby be assumed to function as an additional cue that helps the learner to focus attention on important information. Comparable to the cueing principle (Van Gog, 2014), the fingers may help the learner to focus the learning relevant elements of a multimedia learning instruction and to guide the learner's attention during mental model construction. Cues for corresponding elements of text and picture information are thereby assumed to reduce cognitive load and to facilitate information integration. A meta-analysis by Schneider, Beege, Nebel, and Rey (2018) confirms a predominant positive effect of cueing on learning performance with a slight decrease in cognitive load and an increase in visual attention for cued elements. However, usually cues are part of the learning material in the form of marks, lines, numbers or kinds of colour coding that were used to highlight important elements of the learning instruction that is similar but still different from cueing information by the use of one's own hands. Reed et al. (2006) analysed the time to target detection for a covert-orienting task and showed that visual attention near the hand is facilitated. Participants detected targets presented near the hand faster than targets presented at a distance from the hand. Moreover, this effect was only apparent for a real hand or a fake hand but not for a visual anchor. The effect was stronger for the conditions in which visual and proprioceptive input about the hand was combined and the effect remained for conditions in which either visual or proprioceptive input was available. The additional facilitating effect of the haptic modality is explained by bimodal visuotactile neurons that respond to tactile stimulation on the hand as well as to visual stimulation near the hand. Abrams et al. (2008) used visual attention tasks to show that visual attention is affected when the hands are close to the stimulus display. The experiments show a facilitating effect for visual search and a slowing down of the shift of attention between items presented near the hands. A study by Cosman and Vecera (2010) extended these findings, showing that hand position acts as a cue and not only affects visual attention but also visual perceptual processing. In sum, these results support the assumption of faster and deeper visual processing of information that is presented close to the hand's position.

With respect to the reported studies, the instruction to point and gesture to specific areas of instructional materials that contain important information should increase the learners' visual attention on those areas and cause a beneficial effect by increasing the information processing of this information. Eye-tracking measures based on fixations show the learners' focus of visual attention while processing the presented information, and according to the assumptions of the eye-mind hypothesis (Just & Carpenter, 1976), fixations also indicate cognitive processing. Several studies show that long fixation durations are an indicator of deep information processing and high cognitive activity (Jarodzka, Scheiter, Gerjets, & van Gog, 2010; Rayner, 1998). While learning with multimedia, the fixation duration on corresponding pictures or graphics is assumed to indicate learning-relevant cognitive processes (Mayer, 2010; Rayner, Li, Williams, Cave, & Well, 2007; Reichle, Rayner, & Pollatsek, 2003). Moreover, the number of transitions between corresponding textual and pictorial information are assumed to represent integrative cognitive processes and to indicate the learners' engagement in schema acquisition (Korbach, Park, & Brünken, 2017, 2018; Schmidt-Weigand, Kohnert, & Glowalla, 2010). Korbach, Brünken, and Park (2017) analysed eye movements while learning from a lesson incorporating seductive details and showed a shift of visual attention for the seductive details group, with perfunctory processing of the learning relevant information that was indicated by lower fixation durations on the learning-relevant picture information. Moreover, the study found a lower number of integrative transitions between corresponding text and picture information for the seductive details group, and a high total number of transitions between all learning-relevant and seductive details information that can be assumed to indicate overall high cognitive activity for total information processing. Another study on that topic (Korbach, Park, & Brünken, 2016) used eye-movement measures as mediators to show that the effect of the learning instruction was mediated by visual information processing and that the differences in learning performance can be explained by a shift of visual attention and related cognitive activity.

With respect to the visual attention explanation, for the present study a similar shift in visual attention and a higher cognitive activity for information processing is expected for the use of pointing and tracing gestures. Thereby the effect of hand presence and haptic modality on visual attention is related to embodied cognition (Wilson, 2002) as this effect of sensorimotor processing originates from an interaction of the physical body and the learning task. One explanation with an even closer relation to embodied cognition is the assumption of embodied memory patterns.

1.2 | Embodied memory patterns

The beneficial effect of pointing and tracing gestures can also be explained by an effect of embodied memory patterns on cognitive performance (Glenberg, 1997) This explanation originates from the assumption that cognition should be considered as embodied when cognitive processing depends on states or features of the learner's physical body in sensing and acting (Wilson & Foglia, 2011). The embodiment thesis about the dependency of cognitive processing and the physical body should be applied to situations with a significant causal or physically constitutive role of the body for cognitive processing. With regard to a learning context, there are situations with a quite natural involvement of the learner's body, for example motor tasks or language learning, but there are also situations with an instructed involvement of the body, as for example tracing gestures on the surface of lesson materials showing mathematical problem-solving (Agostinho et al., 2015). According to theories of embodied cognition (Glenberg, Witt, & Metcalf, 2013), cognitive processes should be assumed to be grounded in the body's interaction with the learning environment and the learning task; for example, finger gesturing and finger counting fosters the understanding of mathematical concepts (Foglia & Wilson, 2013). The bodily interaction with the learning task can support the construction of mental representations, off-load cognitive processes to the learning environment and reduce cognitive workload. For instance, finger gesturing is assumed to enhance the construction of mental representations about spatial relationships and positions (Wilson, 2002). One central claim of embodied cognition is the connection between cognition and motoric movements especially for visually guided actions and the priming of motor activity (Wilson, 2002) but also for embodied memory patterns (Glenberg, 1997). Memory is therefore assumed to encode perceptuomotor patterns of physical interactions and situations or objects with a functional relevance. With regard to the learning task of the present study that involves hand and finger gesturing, the relation between action and perception should be considered, as perception is influenced by the presence of one's hand and the possibility to act (Glenberg et al., 2013). Thus, the presence of the hand and specifically the tracing gestures along functional structures of the human heart in the graphical information might enhance the processing of visuo-spatial information and cause an enactment effect (Glenberg, 1997) that enhances memory performance and recall. Moreover, the pointing and tracing gestures should foster the processing of structural and spatial information of the human heart and facilitate the construction of a mental representation. In sum, the effect of pointing and tracing gestures on the surface of learning materials should foster the development of embodied memory patterns and reduce cognitive workload by off-loading cognitive work as a function of the learner's bodily interaction with the learning task.

The last explanation assumes a decrease of cognitive workload too and is also related to the embodiment of cognition but with an evolutionary background of human development.

1.3 | Cognitive load

Cognitive load theory (CLT; Kalyuga, 2011; Leppink & Van den Heuvel, 2015; Plass et al., 2010; Sweller, 2010; for the historical development of the theory see Moreno & Park, 2010) assumes that learning is a process that consumes cognitive resources and is therefore limited by the learner's working memory capacity. Moreover, the theory assumes two types of load, intrinsic cognitive load that is inherent to the complexity of the learning task, and extraneous cognitive load as a result of the instructional design and the presentation format. In addition, germane cognitive resources represent the amount of working memory capacity that is actively used to deal with intrinsic cognitive load (Choi, van Merrienboer, & Paas, 2014). Germane cognitive resources thereby replace the former germane cognitive load factor of the three-factorial model of CLT (Sweller, van Merriënboer, & Paas, 1998) with the assumption of a separate cognitive load consumption by mental model construction. Based on Geary's (2008) approach of an evolutionary educational psychology, the evolutionarily informed upgrade of CLT (Paas & Sweller, 2012) integrates the assumption that the acquisition of biologically primary knowledge (e.g., nonverbal behaviour, theory of mind or facial expression) is quite effortless and rarely consumes cognitive capacity. In contrast, the acquisition of biologically secondary knowledge (e.g., reading or mathematical knowledge) requires effort and a comparatively large amount of cognitive resources. According to this assumption the use of biologically primary knowledge to gain biologically secondary knowledge can reduce the necessary effort and cognitive capacity. Therefore, the basic explanation concerning the beneficial effects of hand or finger gesturing for learning is that these body movements are forms of biologically primary knowledge that foster gaining biologically secondary knowledge. The sensorimotor perception of the hands might facilitate learning as the use of hands has a strong evolutionary background concerning exploring, explaining and understanding as well as concerning communication (Liszkowski, Brown, Callaghan, Takada, & De Vos, 2012; Steinbach & Held, 1968).

The use of biologically primary knowledge to gain biologically secondary knowledge may extend the limitations of human cognitive capacity by consuming less cognitive resources and saving cognitive capacity. In case of hand and finger gestures, the highly developed sensorimotor perception of the hands might facilitate learning as the cognitive demands of a learning task might be reduced when these advantages of perception and processing are used for learning. Moreover, finger gesturing and the involvement of the basic motor system may not only reduce cognitive demands but also enhance the construction of high-quality cognitive schemas due to the embodiment of cognitive processing and an increased task-learner interaction (Paas & Sweller, 2012). This assumption is supported by a study of Ping and Goldin-Meadow (2010) that shows gesturing to improve task performance by means of lower cognitive load. A study by Pouw et al. (2016) gives further support, showing fewer eye-movements for participants while gesturing during mentally solving the Tower of Hanoi problem. Although problem-solving performance was not affected by gesturing, participants showed significantly fewer saccades for the gesturing trials in contrast to the no-gesturing trials and the decrease in the number of saccades was stronger for participants with low visual working memory. The results suggest that gestures can compensate for high cognitive load by offloading visual working memory processes; the authors explained the effect by additional proprioceptive monitoring for gestures that helps to handle the mental representation.

In contrast to the studies presented above (Abrams et al., 2008; Cosman & Vecera, 2010; Reed et al., 2006), Pouw et al. (2016) used gestures in combination with a virtual task and there was no additional tactile information. However, the assumption of bimodal visuotactile neurons that make use of additional tactile information to facilitate visual processing near the hand (Cosman & Vecera, 2010) is also consistent with CLT and the assumption of more efficient and resource-saving cognitive processing by the use of an additional modality. In sum, CLT can explain the effect of pointing and tracing gestures by changes in cognitive capacity consumption with regard to all of the reported theoretical explanations. Changes in cognitive load can either be related to assumptions of visual attention guidance and a deeper, more efficient information processing, as well as to assumptions of embodied memory patterns with a resource saving embodiment of cognitive processing, or the evolutionarily informed assumptions with the resource saving function of biological primary knowledge. However, in contrast to the embodiment and the evolutionary theorizing, the visual attention explanation does not necessarily need a decrease in intrinsic or extraneous cognitive load to explain a beneficial effect on learning performance. Following this explanation, the use of finger gestures could also foster information processing and add cognitive activity for mental model construction without changing perceived task complexity or comprehensibility of the learning instruction.

1.4 | Previous research

Macken and Ginns (2014) showed a beneficial effect for pointing and tracing gestures with the index finger while learning with a multimedia lesson (paper-based expository text with diagrams) about the anatomy of the human heart. Participants in the pointing and tracing group were instructed to use their fingers to make connections between corresponding text and picture information. Participants' index fingers could be used to point to relevant text passages with one hand, with the other hand used to point to the corresponding information in the graphic. Participants were thus free to use more than one finger and to leave the finger on the graphic information while reading the corresponding text passages. Moreover, participants were instructed to trace along arrows in the graphic that indicate blood flow between heart chambers. The main hypothesis was that the pointing and tracing group would learn more effectively as demonstrated by test performance, while reporting lower ratings of extraneous and higher ratings of germane cognitive load. Although the pointing and tracing group outperformed the control group in subsequent terminology and comprehension tests, the gesturing had no significant effects on the learners' ratings of extraneous or intrinsic cognitive load. A further study by Hu et al. (2015) used explicit tracing instructions for geometry worked examples and confirmed the beneficial effect of tracing gestures. The first experiment compared a tracing group with a control group, with the tracing group demonstrating better test performance and lower ratings of test item difficulty, interpreted as enhanced schema construction due to the tracing gestures. The second experiment compared a tracing on the surface group with a tracing above the surface group and a no-tracing control group to focus on the impact of the kinaesthetic component of the tracing gestures. Results support the inclusion of the tactile modality for tracing instructions as the tracing on the surface group showed the highest learning performance. With regard to the approach of an evolutionary educational psychology (Geary, 2008) pointing and tracing gestures were discussed to be a form of biological primary knowledge that facilitates the gain of biological secondary knowledge. A study by Agostinho et al. (2015) also used explicit tracing instructions but in combination with a digital learning instruction about temperature graphs that was presented on a tablet. The results again confirm the beneficial effect of pointing and tracing gestures and in contrast to the former studies that used paper learning instructions, this time for the presentation on touch screens. The results are discussed with regard to the evolutionarily informed upgrade of CLT (Paas & Sweller, 2012) and the concept of biological primary and secondary knowledge (Geary, 2008); however, results for self-reports of cognitive load have been inconsistent across studies.

1.5 | Goal of the present study

The goal of the present study was to examine the effect of pointing and tracing gestures on learning performance, visual information processing and cognitive load in a between-subjects design. The lesson on the human heart used by Macken and Ginns (2014) was used to replicate the results and to investigate how pointing and tracing gestures affect the learning process. As the theoretical explanations described above can all be related to assumptions about the embodiment of cognition and according changes in cognitive capacity consumption, an exclusive explanation is not necessarily expected.

Hypothesis 1. *With regard to the reported studies about the effect of pointing and tracing gestures on learning performance, it is assumed that the pointing and tracing group will outperform the control group in learning success.*

Hypothesis 2. *According to the visual attention explanation, it is assumed that eye movements will indicate a shift of visual attention with longer fixation durations on the illustration information and higher cognitive activity for information integration with a higher number of transitions for the pointing and tracing group. If so, the effect of pointing and tracing gestures on learning success should moreover be mediated by eye movements.*

Hypothesis 3. *With regard to the assumption of embodied memory patterns, it is assumed that the subjective ratings of cognitive load will be lower for the pointing and tracing group as the bodily interaction might facilitate cognitive processing due to the usage of additional, embodied cognitive resources. It is further assumed that an intense bodily interaction with the learning task, as indexed by a high number of pointing and tracing gestures is related to high learning success.*

Hypothesis 4. *According to the assumptions of evolutionarily informed cognitive load theory, it is assumed that the subjective ratings of cognitive load will be lower for the pointing and tracing group as pointing and tracing gestures might facilitate cognitive processing due to the resource saving functions of biological primary knowledge.*

2 | MATERIAL AND METHODS

2.1 | Participants

G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) was used for power analysis with a preset power of.8. With regard to previous studies, a medium to large effect size was expected for learning performance and visual attention that resulted in a suggestion of 48 participants. With regard to missing effects on cognitive load in previous studies and with regard to the study of Macken and Ginns (2014) the final sample size was raised to 60 participants. All participants were university students and were randomly assigned to one of the two groups (mean age = 23.67 years, *SD* = 5.57; 88.9% female). The evaluation went on until the planned sample size (*N* = 60) with complete data sets and full recordings of gaze behaviour for all participants was reached. Participation was on a voluntary basis and informed consent was obtained from all individual participants included in the study.

2.2 | Materials and procedure

The original paper-based learning instruction about the human heart developed by Dwyer (1972) was translated into German, converted to a digital version and adapted for eye tracking on a 23-inch touch screen monitor with a resolution of 1920 × 1080 pixels (including pre- and post-tests). In comparison to the version of the learning instruction used by Macken and Ginns (2014) the text information for each slide was summed up to a coherent text section and the distance between text and picture information was enlarged (see Figure 1). A two-group design was used with pointing and tracing gestures as between subjects factor (with vs. without pointing and tracing). Both groups worked with a system-paced multimedia learning program about the structure and function of the human heart. Time on task was constant for the learning task. The program consists of 14 slides presenting information in form of illustrations on the right side and corresponding text on the left side of each slide (see Figure 1). Corresponding elements of text and illustration are marked with corresponding numbers and the important areas of the illustration are highlighted with arrows for both groups. The learning phase with the presentation of the slides lasted about 25 minutes that was interrupted by the cognitive load rating scale after slide eight at about 12:50 minutes of learning time. The pointing and tracing group was instructed to use their fingers to point and trace on the learning instruction according to the instructions used by Macken and Ginns (2014). With regard to the different theoretical explanations, the instruction includes the key-features with the presence of hands and fingers, the additional haptic modality and movement interaction as follows:

'Please use your hands where you need to make a link between text and an associated part of the diagram. Some ways you may like to do this:

- Point with a finger of your left hand at the word in the text, then point with a finger of your right hand at the corresponding location on the diagram
- Leave your finger of the right hand on the diagram as you read about the corresponding element in the text
- Use more than one finger/hand to simultaneously point to parts of text and the diagram that are related
- Where you see arrows indicating blood flow, use a finger of your right hand to trace along the arrows.
- Use the index finger of your right hand to trace over corresponding elements in the diagram when they are introduced by the text'

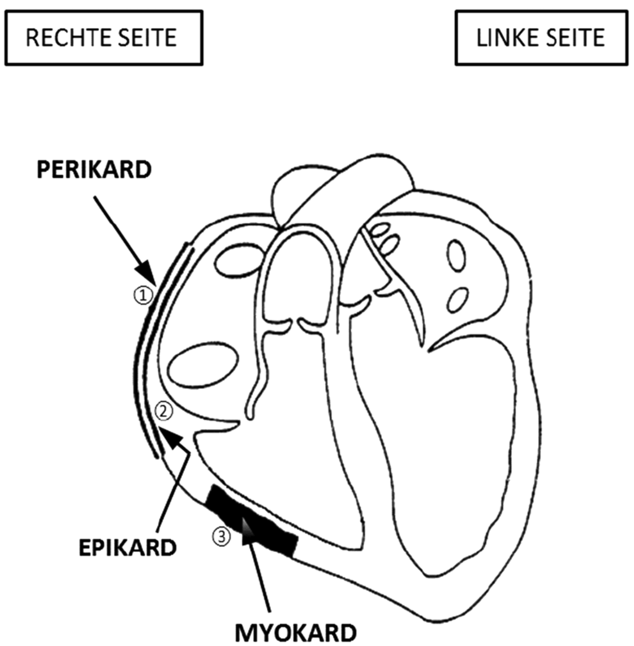

FIGURE 1 Example slide of the learning instruction

In contrast, the control group was instructed to rest their hands beside the touch screen.

Eye movements were recorded while learning with a Tobii x2-60-compact eye tracker and analysed with Tobii-Studio software. Eye-tracker settings for the touch screen display were adjusted using the Tobii X-Config tool. The system was calibrated using a nine-point calibration, immediately before the recording of eye movements started. Calibration results were checked visually and only participants with proper hits on all nine calibration points were included. Areas of Interest (AOIs) were set for the textual as well as for the pictorial information on each slide and with respect to former studies that showed the importance of pictorial information for the learning process (Korbach, Brünken, & Park, 2016; Park, Korbach, & Brünken, 2015), for the regions of the illustration that contained the important information that should be pointed to and traced. The important pointing and tracing areas were visually cued for both groups (see Figure 1). The analysis of eye-tracking data focused on the total fixation duration, the time to first fixation on the previously defined AOIs and on the transitions between the corresponding text and illustration AOIs. Fixation duration and the time to first fixation primarily served as indicators for the focus of visual attention and the number of transitions served as an indicator of cognitive activity. The first text AOI on the instruction slide that contained the same information for both groups was used to control for general group differences in eye movements. Eye-movements were filtered using the Tobii Fixation Filter settings with a duration threshold of 100 ms, a velocity threshold of 35 pixel and a distance threshold of 35 pixel. Moreover, the Tobii validity index and the sample quality of the eye movement recordings were used to ensure the comparability of the groups. The Tobii validity index goes from zero to four, where zero indicates high validity and four indicates that the pupil was not properly found for the recorded eye-movement. Sample quality was calculated as proportion of gaze duration on learning time.

The learners' pointing and tracing gestures were recorded and differentiated automatically by the software that presented the learning instruction. Touch events on the screen with a positional change of at least 1cm without losing contact to the touch screen were coded as tracing gestures and touch events on the screen without positional change were coded as pointing gestures.

Learning performance was assessed with three separate tests for comprehension (Cronbach's α = .80), identification (Cronbach's α = .83) and terminology (Cronbach's α = .84), each consisting of 20 multiple choice questions. For the comprehension test participants had to choose the correct answer out of four alternatives concerning the state or activity of single parts of the human heart (e.g., 'Which valve is most like the tricuspid in function?' A. Pulmonary, B Aortic, C. Mitral, D. Superior Vena Cava). For the identification test participants had to select the matching name out of five alternatives for the single parts of the heart that were marked with corresponding numbers in a figure of the human heart. For the terminology test participants had to select the correct term out of five alternatives to complete a given sentence (e.g., 'When blood returns to the heart from the lungs, it enters the ______' A. Left Auricle, B. Pulmonary Valve, C. Left Ventricle, D. Right Ventricle, E. Pulmonary Artery).

Following the revised version of CLT considering only extraneous and intrinsic cognitive load with an inherent relation to germane cognitive resources (Choi et al., 2014), cognitive load was measured by a translated and adapted version of an eight item cognitive load rating scale by Leppink and Van den Heuvel (2015). Four items were intended to measure intrinsic cognitive load on a ten point Likert scale (e.g., 'The content of the learning instruction was very complex') after slide eight (Cronbach's α = .92) and after slide fourteen (Cronbach's α = .96). A further four items were intended to measure extraneous cognitive load (e.g., 'The information and explanations of the learning instruction were presented in an ambiguous way') after slide eight (Cronbach's α = .65) and after slide fourteen (Cronbach's α = .83). With regard to the theoretical explanations for the pointing and tracing effect, the measurement of intrinsic and extraneous cognitive load should be sufficient, as the embodiment and the evolutionary theorizing primarily assume a decrease in cognitive load specifically for these two cognitive load factors. A possible increase in cognitive activity for mental model construction that is not related to changes in intrinsic or extraneous cognitive load and therefore fits to the former concept of germane cognitive load (Sweller, Van Merrienboer, & Paas, 1998) should be indicated by eye-tracking data with a deeper and successful information processing.

Prior knowledge, working memory capacity, spatial ability and learning motivation served as control measures. Prior knowledge was measured by 20 multiple choice questions (Cronbach's α = .42) adapted from Dwyer (1972) concerning heart specific topics and general human and biological facts (e.g., 'The backward flow of blood in the veins is prevented by' A. muscles, B. Valves, C. The heartbeat, D. Lymphatics, or 'The ribs protect the' A. Stomach, B. Breastbone, C. Spinal Cord, D. Lungs). The questions concerning prior knowledge cover very different issues about biology that might be the reason for the low reliability. This prior knowledge test was accepted for analysis because it only served as a control measure. Visuospatial working memory capacity was measured by a Corsi Block tapping test (Schellig & Hättig, 1993), in which participants had to tap on blocks on a block board in a previously demonstrated order. The block sequence was increased by the investigator until participants produced three fails in row and the maximal sequence length with at least two correct trials represents the individual visuospatial block span. Spatial ability was measured by a standardized paper-folding and card-rotation test (Ekstrom, French, Harmann, & Dermen, 1976) and learning motivation was measured by 15 items out of the Inventory of School Motivation (Cronbach's α = .74; McInerney & Sinclair, 1991) that were rated on 5-point Likert scales. Five items were chosen from the subscale 'future goals' (Cronbach's α = .66, e.g., 'I like it to see that my learning performance improves'), five items from the subscale 'mastery' (Cronbach's α = .73; e.g., 'I really want to understand the learning topic') and five items from the subscale 'interest' (Cronbach's α = .56; e.g., 'I want to learn something about interesting topics').

Participants started with a descriptive questionnaire, followed by the questionnaire for learning motivation, the test of working memory capacity, spatial ability and the test for prior knowledge. The eye tracking system was calibrated immediately before the presentation of the learning instruction and when the recording of eye movements was started. After the last slide of the learning instruction and before the post-test questions for learning success the recording of eye movements was stopped.

2.3 | Data analysis

All participants (N = 60) that were considered for analysis had complete data sets, including results of all pre- and post-tests in combination with continuous recordings of eye-movements during the learning phase and complete ratings of cognitive load at both times of measurement. All recordings of eye-movements showed a proportion of gaze duration on learning time over 86% (M = 99.12, SD = 1.89). The Tobii validity index for the analysed fixations was about.36 with a maximum of 1.31 and indicates high validity for the used recordings.

In the present data analysis ANOVAs were conducted for the control variables. The first MANOVA was conducted for learning performance, with the subscales comprehension, identification and terminology. The second MANOVA was conducted for cognitive load ratings, with the ratings of intrinsic and extraneous cognitive load at both times of measurement. The third MANOVA was conducted for the global eye-movements on text and illustration AOIs, with total fixation duration, time to first fixation and transitions. The fourth MANOVA was conducted for the task specific eye movements on the pointing and tracing areas of the illustration, with total fixation duration, time to first fixation and number of transitions. For all tests of significance, α = .05 was applied as level of significance. In the case that Levene's test indicated inequality of variances, the Welch test was used to recheck the results of the MANOVAs; however, the results of the Welch test are not reported when they confirmed the results of the MANOVAs. The correlations between the measures of learning performance, cognitive load and eye movements were analysed to get a first impression about the relations among the dependent variables and to identify potential mediators for the following regression-based approach for conditional process modelling by Hayes (2013). With regard to the studies of Korbach et al. (2016) and Park et al. (2015) simple mediation models were conducted using eye-movement measures as mediators to assess an indirect effect of pointing and tracing gestures on learning performance. The number of bootstrap samples to test the indirect path was set to 10 000, the level of confidence for all confidence intervals was set to 95% and significance was assumed (p < .05) for numerical values between the lower level of confidence interval (LLCI) and the upper level of confidence interval (ULCI) that were different from zero. The additional analysis for the prior knowledge items is not reported as the results are in line with the result for the complete prior knowledge test.

3 | RESULTS

The two groups did not differ significantly concerning prior knowledge, $F(1, 58)$ = .34 *n.s.*, working memory capacity, $F(1, 58)$ = 1.98, *n.s.*, spatial ability, $F(1, 58)$ = 2.90, *n.s.*, learning motivation, $F(1, 58)$ = 2.70, *n.s.*, the fixation duration of the info text on the instruction slide, $F(1, 52)$ = 1.12, *n.s.*, or the quality $F(1, 58)$ = .08, *n.s.*, and validity of the eye movement records, $F(1, 58)$ = .01, *n.s.*. All participants of the pointing and tracing group showed pointing events on text (M = 198.93, SD = 272.32) as well as pointing (M = 349.94, SD = 664.17) and tracing (M = 2202.94, SD = 3863.77) events on the illustration (see Table 1).

The results of the MANOVA for learning performance showed no overall effect for learning instruction, Λ = .92, $F(3, 56)$ = 1.63, *n.s.*. Univariate testing showed a significant group difference for the performance in the identification test, $F(1, 58)$ = 4.16, p = .046, η^2 = .07, with significantly higher performance for the tracing and pointing group. No significant group differences were found for the performance in the comprehension test, $F(1, 58)$ = .54, *n.s.*, or terminology test, $F(1, 58)$ = 1.30, *n.s.* (see Table 2).

The results of the MANOVA for cognitive load ratings showed no overall effect for learning instruction, Λ = .96, $F(4, 55)$ = .52, *n. s.*. Univariate testing showed no group difference for intrinsic cognitive load, $F(1, 58)$ = 1.06, *n.s.*, and for extraneous cognitive, $F(1, 58)$ = .06, *n.s.*, after slide 8 and no group difference for intrinsic, $F(1, 58)$ = .04, *n.s.* and extraneous, $F(1, 58)$ = .12, *n.s.* cognitive load after slide 14 (see Table 3).

The results of the MANOVA for eye movements showed an overall effect for learning instruction, Λ = .63, $F(5, 54)$ = 6.37, p < .001, η^2 = .37. Univariate testing showed significant group differences for fixation duration on text AOIs, $F(1, 58)$ = 7.67, p = .008, η^2 = .12 and on illustration AOIs, $F(1, 58)$ = 9.47, p = .003, η^2 = .14, with longer fixation duration on the illustration AOIs and shorter fixation duration on the text AOIs for the pointing and tracing group. There was no significant group difference found for the mean time to first fixation on the text AOIs, $F(1, 58)$ = .23, *n.s.*, or the illustration AOIs, $F(1, 58)$ = 3.35, p = .072, η^2 = .06. However, the total number of transitions between text and corresponding illustration AOIs showed a significant group difference, $F(1, 58)$ = 28.41, p < .001, η^2 = .33, with a higher number of transitions for the pointing and tracing group (see Table 4).

TABLE 1 Means and Standard Deviations for Control Variables

	Pointing & tracing n = 30		No pointing & tracing n = 30	
	M	(SD)	M	(SD)
Prior knowledge (%)	59.0	(11.10)	57.15	(13.31)
Working memory (max. 9)	5.53	(.82)	5.87	(1.01)
Spatial ability (%)	69.29	(14.95)	61.83	(18.74)
Learning motivation (max. 75)	62.57	(3.67)	64.13	(5.53)
Fixation duration (sec.)	8.07	(4.85)	10.79	(6.10)
Sample quality (%)	88.70	(7.81)	88.33	(7.82)
Validity index (max. 4)	.36	(.22)	.37	(.28)

Note. M = mean; SD = standard deviation.

TABLE 2 Means and Standard Deviations for Learning Success in %

	Pointing & tracing n = 30		No pointing & tracing n = 30	
	M	(SD)	M	(SD)
Comprehension	75.21	(19.10)	71.16	(23.31)
Identification	89.38	(14.14)	78.48	(25.65)
Terminology	74.36	(17.33)	67.76	(26.51)

Note. M = mean; SD = standard deviation.

TABLE 3 Means and Standard Deviations for Cognitive Load

	Pointing & tracing n = 30		No pointing & tracing n = 30	
	M	(SD)	M	(SD)
Intrinsic cognitive load after slide 8 (max. 10)	6.34	(1.86)	6.85	(1.96)
Extraneous cognitive load after slide 8 (max. 10)	2.54	(1.38)	2.63	(1.32)
Intrinsic cognitive load after slide 14 (max. 10)	6.33	(2.08)	6.45	(2.27)
Extraneous cognitive load after slide 14 (max. 10)	2.71	(1.53)	2.58	(1.46)

Note. M = mean; SD = standard deviation.

The results of the MANOVA for the detailed pointing and tracing areas of the illustration also showed an overall effect for learning instruction, $\Lambda = .64$, $F(3, 56) = 10.48$, $p < .001$, $\eta^2 = .36$. Univariate testing showed a significantly higher fixation duration on the pointing and tracing areas of the illustration AOIs, $F(1, 58) = 14.36$, $p < .001$, $\eta^2 = .20$, with longer fixation duration for the pointing and tracing group. Moreover, there was a significant group difference for the mean time to first fixation on the pointing and tracing areas of the illustration AOIs, $F(1, 58) = 6.21$, $p = .016$, $\eta^2 = .10$, with a significantly faster first fixation on the pointing and tracing areas of the illustration for the pointing and tracing group. Finally, there was a significant group difference for the transitions between text and the corresponding pointing and tracing areas of the illustration, $F(1, 58) = 26.52$, $p < .001$, $\eta^2 = .31$, with a higher number of transitions for the pointing and tracing group (see Table 4).

Several significant correlations (see Table 5) underline the beneficial impact of the change in information processing on learning success when learning with the pointing and tracing method. Fixation durations on the pointing and tracing areas of the illustrations as well as transitions between text and the corresponding pointing and tracing areas of the illustrations are positively related to learning success. This is shown by significant positive correlations between the variables, for example concerning comprehension performance correlated with illustration fixation duration, $r = .42$, $p = .001$, as well as with transitions, $r = .26$, $p = .048$, and identification performance correlated with illustration fixation duration, $r = .29$, $p = .027$, as well as with transitions, $r = .40$, $p = .001$. Moreover, a significant negative correlation was found between the time to first fixation on illustration and learning success, specifically the identification test, $r = -.45$, $p < .001$, relating a faster first fixation on illustrations with higher learning performance. The negative and significant correlations between the cognitive load ratings and learning success (see Table 4) indicate that learners rather rated the part of cognitive load that results from task complexity or problems with the presentation format than from a successful learning process. Moreover, significant correlations were found between the cognitive load ratings and the eye movements. Correlations show the following relation: The higher intrinsic cognitive load ratings the shorter the fixation duration, $r(\text{t1}) = -.38$, $p = .003$; $r(\text{t2}) = -.35$, $p = .005$, and the longer the time to first fixations, $r(\text{t1}) = .284$, $p = .028$, on the pointing and tracing areas of the illustration. In addition, high extraneous cognitive load ratings are related to fewer transitions between text and the corresponding pointing and tracing areas of the illustrations, $r(\text{t2}) = -.28$, $p = .033$.

TABLE 4 Means and Standard Deviations for Eye Movements

	Pointing & tracing $n = 30$		No pointing & tracing $n = 30$	
	M	*(SD)*	*M*	*(SD)*
Text fixation duration (sec.)	894.60	(125.25)	988.48	(137.02)
Illustration fixation duration (sec.)	412.05	(98.20)	326.54	(116.29)
Time to first fixation on text AOIs (sec.)	0.74	(0.69)	0.67	(0.44)
Time to first fixation on illustration AOIs (sec.)	2.48	(2.37)	4.10	(4.23)
Transitions between text and illustration AOIs (N)	164.67	(45.62)	105.60	(40.04)
P & T areas of illustrations fixation duration (sec.)	272.13	(67.73)	197.21	(84.48)
Time to first fixation on P & T illustration AOIs (sec.)	6.79	(3.03)	10.56	(7.70)
Transitions between text and P & T areas of illustration AOIs (N)	102.73	(36.05)	58.90	(29.57)

Note. P & T = pointing and tracing; *M* = mean; *SD* = standard deviation; *N* = number.

With regard to the correlations between learning performance and eye movements the regression-based approach for conditional process modeling (Hayes, 2013) was used to further analyse the effect of pointing and tracing on learning performance considering the eye movement indicators for cognitive activity. Separate mediation analyses were conducted for the potential mediators of fixation duration on the tracing areas of the picture AOI, time to first fixation on the tracing areas of the picture AOI and the number of transitions towards the tracing areas of the picture AOI. The three models were only conducted for identification test performance as the results of the MANOVA showed significant group differences only for this kind of learning performance. The number of bootstrap samples was set to 10 000.

The results for fixation duration show a significant regression model for identification performance, $F(2, 57) = 3.96$, $R^2 = .22$, $p = .025$, with a significant effect for fixation duration on learning performance, $t(57) = 2.64$, $\beta = .012$, $p = .011$, no direct effect of pointing and tracing gestures, $t(57) = .60$, $\beta = .296$, *n.s.*, and a full mediation of learning performance by fixation duration, BootLLCI = .2641, BootULCI = 2.1367. The results for time to first fixation also show a significant regression model for identification performance, $F(2, 57) = 3.70$, $R^2 = .22$, $p = .031$, with a significant effect for time to first fixation on learning performance, $t(57) = -2.41$, $\beta = -.155$, $p = .019$, no direct effect of pointing and tracing gestures, $t(57) = 1.19$, $\beta = .615$, *n.s.*, and a full mediation of learning performance by time to first fixation, BootLLCI = .1232, BootULCI = 1.4400. The results for transitions again show a significant regression model for identification performance, $F(2, 57) = 3.25$, $R^2 = .16$, $p = .046$, with a significant effect for the number of transitions on learning performance, $t(57) = 2.17$, $\beta = .022$, $p = .034$, no direct effect of pointing and tracing gestures, $t(57) = .38$, $\beta = .223$, *n.s.*, and a full mediation of learning performance by the number of transitions, BootLLCI = .3469, BootULCI = 2.1034.

For a first analysis of the bodily interaction between learner and learning instruction by pointing and tracing gestures, correlations ($N = 30$) were analysed for the number of pointing and tracing events and learning success. Results show no significant correlations but negative ones between touch events on the illustrations and the identification test (see Table 6). Although these results are limited because of the small sample size, the correlations for pointing and tracing gestures suggest that less activity is related to higher learning success for the given learning instruction.

In sum, the results confirm hypothesis 1 and 2, with a beneficial effect of pointing and tracing gestures for identification performance

TABLE 5 Bivariate Correlations for Dependent Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Comprehension	1	-	-	-	-	-	-	-	-	-	-
(2) Identification	$.679^{**}$ $p < .001$	1	-	-	-	-	-	-	-	-	-
(3) Terminology	$.668^{**}$ $p < .001$	$.761^{**}$ $p < .001$	1	-	-	-	-	-	-	-	-
(4) ICL (t1)	$-.487^{**}$ $p < .001$	$-.431^{**}$ $p = .001$	$-.479^{**}$ $p < .001$	1	-	-	-	-	-	-	-
(5) ECL (t1)	$-.459^{**}$ $p < .001$	$-.526^{**}$ $p < .001$	$-.507^{**}$ $p < .001$	$.451^{**}$ $p < .001$	1	-	-	-	-	-	-
(6) ICL (t2)	$-.438^{**}$ $p < .001$	$-.315^{*}$ $p = .014$	$-.422^{**}$ $p = .001$	$.751^{**}$ $p < .001$	$.203$ $p = .120$	1	-	-	-	-	-
(7) ECL (t2)	$-.300^{*}$ $p = .020$	$-.434^{**}$ $p = .001$	$-.322^{*}$ $p = .012$	$.297^{*}$ $p = .021$	$.615^{**}$ $p < .001$	$.306^{*}$ $p = .017$	1	-	-	-	-
(8) Text fixation duration	$-.185$ $p = .157$	$-.228$ $p = .080$	$-.196$ $p = .133$	$.286^{*}$ $p = .027$	$.221$ $p = .090$	$.244$ $p = .060$	$.240$ $p = .064$	1	-	-	-
(9) Illustration fixation duration (P & T)	$.417^{**}$ $p = .001$	$.286^{*}$ $p = .027$	$.320^{*}$ $p = .013$	$-.380^{**}$ $p = .003$	$-.116$ $p = .379$	$-.354^{**}$ $p = .005$	$.059$ $p = .653$	$-.323^{*}$ $p = .012$	1	-	-
(10) Illustration time to first fixation (P & T)	$-.225$ $p = .083$	$-.447^{**}$ $p < .001$	$-.242$ $p = .063$	$.284^{*}$ $p = .028$	$.122$ $p = .352$	$.209$ $p = .109$	$.128$ $p = .331$	$.306^{*}$ $p = .018$	$-.116$ $p = .379$	1	-
(11) Text to illustration transitions (P & T)	$.256^{*}$ $p = .048$	$.403^{**}$ $p = .001$	$-.253$ $p = .051$	$-.100$ $p = .447$	$-.173$ $p = .187$	$-.106$ $p = .419$	$-.276^{*}$ $p = .033$	$-.184$ $p = .160$	$.041$ $p = .757$	$-.554^{**}$ $p < .001$	1

Note. P & T = Pointing and Tracing.

that can be explained by a shift of the focus of visual attention from text to illustration processing and a high cognitive activity for the integration of the corresponding text and illustration information. As expected, the results of the mediation analyses show that the shift in visual attention indeed explains the positive effect on identification performance. However, hypothesis 3 and 4 were not confirmed, as the results show in general no effect for the rating of extraneous or intrinsic cognitive load. Moreover, the negative correlations between learning performance and the number of pointing and tracing gestures rather support the visual attention guidance explanation than the assumption of embodied memory patterns, as an intense bodily interaction was not related to higher learning success.

4 | DISCUSSION

The results of the present study are in line with the results of Macken and Ginns (2014), this time with a beneficial effect for the pointing and tracing group on identification performance and no effect on subjective ratings of cognitive load. With respect to the theoretical assumptions, the results support the explanation that pointing and tracing gestures primarily affect the visual focus of attention (Cosman & Vecera, 2010; Reed et al., 2006) although there was no general increase in the visual focus of attention but a shift towards picture processing in the present study. Participants in the pointing and tracing group focused more on the pictorial information and invested more cognitive activity for the integration of the text and corresponding picture information. The important pictorial information was fixated faster and longer, and a higher number of transitions were performed by the pointing and tracing group with significant correlations with higher learning performance. The results of the eye-movement analysis are in line with the study of Korbach et al. (2017); Korbach, Brünken, and Park (2018) and support the assumption that the visual attention directed to pictorial information, as well as the number of transitions, is related to cognitive activity for integrative cognitive processes and mental model construction when learning with multimedia (Mayer, 2010; Rayner et al., 2007; Reichle et al., 2003). In contrast to the study of Pouw et al. (2016), the eye movements of the pointing and tracing group of the present study showed more cognitive activity for information processing that might be due to different task demands, with text-graphic transitions and saccades indicating different task-specific cognitive processes. However, for both studies, gesturing modified the visual information processing, and both studies are in line with the assumption that hand and finger gesturing guides the focus of visual attention and enhances information processing.

TABLE 6 Bivariate Correlations for Learning Success and Haptic Behaviour

	Comprehension	Identification	Terminology
Pointing text	$-.051$ $p = .787$	$-.147$ $p = .437$	$-.281$ $p = .133$
Pointing illustration	$-.197$ $p = .298$	$-.429^{*}$ $p = .018$	$-.246$ $p = .190$
Tracing illustration	$-.294$ $p = .115$	$-.490$ $p = .006^{**}$	$-.251$ $p = .182$

With regard to the embodiment of cognition, the results of the present study provide no support for an off-loading of cognitive processes or an increase in processing efficiency (Wilson, 2002) that should be indicated by lower cognitive load ratings for the pointing and tracing group and lower cognitive activity indicated by eye movements. The shift in visual attention for the pointing and tracing group is partially in line with the embodiment hypothesis as the use of hands and fingers that increased visual attention is a kind of physical interaction with the learning task. However, the negative correlations between learning success and the number of pointing and tracing events do not support the assumption about a beneficial effect of action itself or intense bodily interaction. One explanation could be that the task demands do not properly fit to the assumptions of the embodiment thesis (Wilson & Foglia, 2011) as the bodily interaction is based on instructed movement that might be artificial compared to natural movements with a closer relation to the actual learning topic. Future studies should control for pointing and tracing gestures by differentiated instruction either to trace or to point in order to get detailed information about the role of movement for memory and recall performance (Glenberg et al., 2013). The results of the present study do not support the assumption of embodied memory patterns or an effect of motoric interaction, but a partial beneficial effect of movement on memory and recall performance cannot be ruled out. Further research should also focus on the quality of gestures with possible different effects of pointing or tracing gestures.

CLT (Choi et al., 2014; Plass et al., 2010) assumes gesturing as a form of biological primary knowledge (Geary, 2008) that can support efficient and resource-saving cognitive processing for the acquisition of biological secondary knowledge. However, the results of the present study do not support the assumption about a resource-saving cognitive processing as there were no differences in the subjective ratings of cognitive load that should be indicated by lower cognitive load ratings for the pointing and tracing group. The eye-movement analysis also shows no support for the assumption of low extraneous cognitive load or low intrinsic cognitive load with regard to task complexity. Compared to the study of Pouw et al. (2016), the present study showed more transitions between corresponding text and picture information for the pointing and tracing group that was positively related to learning success and that mediated the effect of pointing and tracing gestures. Moreover, the use of the additional tactile modality can also be assumed not to reduce cognitive load but to guide the visual information processing and to facilitate the process of shifting visual attention (Cosman & Vecera, 2010). The only indicator that hints towards a group difference in cognitive load is the number of transitions, indicating a higher cognitive activity for the pointing and tracing group. As the number of transitions shows a positive correlation to learning success, the transitions can be assumed to indicate learning-relevant and successful cognitive processes in this study. This result is in line with the assumptions of Macken and Ginns (2014) concerning an increase in germane cognitive load as a function of deeper information processing in the former model of cognitive load theory (Sweller et al., 1998) that was probably not measured by the used rating scale. The results support the assumption that mental model construction can be fostered by pointing and tracing instructions without an increase or decrease in perceived task complexity as it is assumed for the revised version of CLT (Choi et al., 2014). The missing group difference concerning the ratings of extraneous cognitive load could be explained by the visual highly salient presentation format for both groups, including numeration for corresponding text and graphic information in combination with visual cues and arrows pointing to relevant structures or highlighting important functions. Perhaps the pointing and tracing gestures might have the additional function to increase salience and to reduce extraneous cognitive load only for a learning instruction that is not that salient.

The assumptions concerning pointing and tracing gestures as a form of biologically primary knowledge (Agostinho et al., 2015; Geary, 2008; Paas & Sweller, 2012) should nevertheless be considered, as the increased visual attention for areas near the hands or fingers might be related to this evolutionary point of view (cf. Steinbach & Held, 1968). The ability to use the hands to explore, manipulate and use objects might have been very important for informal learning and cognitive development across human evolution, and it follows that humans can continue to benefit from using the hands to construct biologically secondary knowledge. This approach is also associated with the work of Montessori (e.g., Montessori, 1912, 1914, 1969) explaining the relation between action and cognition and her developed haptic learning methods. Typical effective methods are tracing on sandpaper for letter learning or haptic methods for phoneme identification (e.g., Bara, Gentaz, & Colé, 2007) and the recognition of geometrical shapes (e.g., Kalenine, Pinnet & Gentaz, 2010). The same might be true for assumptions of cognitive affective theory of learning with media (CATLM, Moreno & Mayer, 2007) concerning the tactile sensory modality. With regard to CATLM, the additional haptic information of pointing and tracing gestures might also facilitate the process of information selection. Many effects considering the haptic modality can be linked to an increased visual attention for the area near the hands and fingers as well as to the assumption of bimodal visuotactile neurons (Reed et al., 2006) that facilitate and increase visual information processing due to additional haptic information. The importance of the haptic modality for pointing and tracing gestures was already shown by Hu et al. (2015) and provides further support for this assumption. As in the present study both groups worked with a visually cued learning instruction and in sum the results are very similar to the effect of visual cueing (Schneider et al., 2018), the additional haptic information by pointing and tracing gestures seems to enhance the effect of visual cues. With regard to the present study, further research should analyse eye movements for comparable conditions with and without additional haptic information to get more information about the impact of the haptic modality. Moreover, the effect of pointing and tracing gestures should be investigated for learning instructions without visual cues to assess the effects on learning performance, cognitive load and information processing when the identification of corresponding elements is part of the task.

One limitation of the study comes along with the instruction for the control group that was not explicitly requested to make connections between text and picture information compared to the pointing and tracing group. However, the related information from text and picture were visually cued (e.g., by numbers) for both groups to refer the necessity to integrate the presented text and picture information to achieve the learning goal. An additional issue was the low reliability of the prior knowledge test, which may have been due to the broad range of topics covered in the test items, many of which went beyond heart physiology. An alternative approach for future research may be to use self-reports of prior knowledge related to the structure and function of the human heart, such as the four-item scale developed by O'Reilly, Symons, and MacLatchy-Gaudet (1998) used by Ginns and Kydd (2019). Using such self-reports circumvents potential issues with generating a testing effect prior to instruction (Parong & Mayer, 2018).

5 | CONCLUSION

In sum, the results of the present study support the explanation of the beneficial effect of pointing and tracing gestures as due to a shift in the focus of visual attention and an increase in cognitive activity for mental model construction. Moreover, the results suggest that the visual attention explanation is not exclusive and can be related to some assumptions of CLT's evolutionarily informed upgrade. However, it is not clear why the participants of the pointing and tracing group focused more on the illustrations as both hands were used for pointing and tracing with the left hand on text and the right hand on illustrations.

An important practical implication of the results is that the way the tracing and pointing gestures were instructed are indeed useful and can be instructed to learners in the same way. Moreover, the present study shows that the tracing method is not only relevant for learning with paper-based material but also with multimedia learning instructions presented on tablets or touch screens. So far, pointing and tracing gestures should be used but they should be used carefully as the results also suggest that more activity is not necessarily associated with higher learning success.

ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained and privacy rights of human subjects were observed. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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