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Comparing Real and Imitative Practice with No Practice during Observational Learning of Hand Motor Skills from Animations

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Abstract: In two experiments, we compared the effects of practice (real and imitative) with no practice on the observational learning of hand motor skills from animated videos. Experiment 1 investigated learning to play a series of piano clips of varying complexity. Results demonstrated improved learning efficiency with imitative practice compared to no practice. Experiment 2 featured a paper-folding task, and results indicated that real practice led to significantly greater learning than no practice. Furthermore, a significant interaction was found with gender and practice, where females learned best with both real and imitative practice, but males did not benefit from these interventions. However, males outperformed females in the no practice condition. Overall, we found benefits of practice versus no practice for both tasks. However, the most effective type of practice was dependent upon the task: imitative practice for piano playing, and real practice for paper folding. Task complexity and gender were also found to be moderating factors.

Keywords: cognitive load theory; embodied cognition; observational learning; practice; gender; instructional animations

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Citation: Mian, M.N.; Beder, H.; Marcus, N.; Ayres, P. Comparing Real and Imitative Practice with No Practice during Observational Learning of Hand Motor Skills from Animations. *Educ. Sci.* **2024**, *14*, 949. https://doi.org/10.3390/educsci14090949

Academic Editor: Dorothe Kienhues

Received: 22 July 2024
Revised: 23 August 2024
Accepted: 26 August 2024
Published: 28 August 2024

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1. Introduction

In educational research, there is a need to design online learning content that is effective for learning across all students and that is relevant to multiple disciplines. Learning using instructional animations [1–3] and incorporating practice [4,5] while learning are both areas that have been studied by many researchers, but mostly independently of each other. The present study addresses this gap by combining both domains to explore when and how it is best to use practice to support learning from instructional animations. By doing so, the study aims to provide a more comprehensive understanding of the interaction between practice and instructional-based animation learning, leading to more effective educational designs. The purpose of this study is to compare the effects of real and imitative practice with no practice for learning two different hand motor-based skills from instructional animations. By investigating these effects, the research can offer practical insights into how educators can better tailor their instructional designs based on the learning domain and learner characteristics, with the end goal of improving learning outcomes across different contexts.

1.1. Instructional Animations

Instructional animations have been used across many domains and have been highly successful in teaching hand motor tasks [1–3,6]. We use the term animations to refer to instructional animations, including both video-based animations and animated graphics, which is consistent with how many researchers have used this term (e.g., [1,2,6–8]). A meta-analysis conducted by Hoffler and Leutner [9] suggests that animations lead to better learning compared to equivalent statics for movement-based tasks. Many studies

have found advantages for animations in tasks like tying knots [10], conducting first aid procedures [11], building Lego shapes [12] and creating origami shapes [8,13].

Cognitive load theory [14] has been used to help explain why instructional animations may be preferred for learning motor tasks based on the mirror neuron system (see [10,13]). A mirror neuron is a type of neuron that has been found to be involved in the learning of motor tasks—it fires when an individual is performing an action or while observing another person performing the same action [15,16]. This has been found to support our ability to engage in imitative learning, although the activation patterns during imitation are not quite as pronounced or the same as during physical practice [17]. Thus, instructional animations of motor tasks may activate these neurons. Additionally, Paas and Sweller [18] argue that movement-based learning can be acquired with less effort, since it is a form of biologically primary knowledge. Biologically primary knowledge refers to what we have evolved to acquire fairly easily without much conscious effort. It involves minimal taxing of our working memory, as it has an innate component to it. Some examples include learning our first language, face recognition, basic human movements, and the ability to interact socially [19–21]. Therefore, arguably, animations displaying human movements may be easier to learn from than those representing mechanical non-human movements.

Some considerations are important to understand when designing instructional animations. The transient nature of animations [22] has been found to cause a burden on our limited working memory, especially in certain contexts, such as dealing with complex information that is high in element interactivity. Information that is high in element interactivity involves multiple interacting elements that need to be simultaneously processed to be understood [23]. However, animations have proven to be effective and superior to statics when the impact of transient information is reduced by dividing the animations into shorter sections with pauses [8]. Additionally, the pace of an animation has the potential to interfere with the quality of the learner's perception of the task and thus inhibit their ability to reproduce the learning task, particularly if the animation speed is high [24]. Moreover, when several interacting elements are required to be processed simultaneously, the increase in intrinsic load may overburden the learner's working memory [23]. Transience, pace, and levels of element interactivity are all factors that need to be considered when developing instructional animations [8,23]. However, considerations of embodied cognition can help alleviate these factors.

1.2. Embodied Cognition

The embodied theory of cognition refers to the linking of the mind with the body and environment [25]. Since action, perception, and cognition are interrelated, it allows for the exploration of how learning can become a bodily experience using human movement. An example of this was demonstrated by Mavilidi et al. [26], who investigated the effect of integrating physical activities into a science lesson for preschool children's learning. Integrating physical activity was found to lead to significantly higher learning outcomes and perceived enjoyment of learning compared to a sedentary style of teaching. Problem-solving for real mechanical systems including pulleys have also been found to improve learning when there were hands-on interactions rather than only referring to diagrams [27]. More recently Chettaoui et al. [28] found benefits to involving body movements with user interfaces such as manipulation of objects, compared to just learning from the interface, for the long-term learning of the basics of human anatomy. Hence, embodied cognition has been found to have benefits when it comes to learning.

In contrast to physical interactions, gesturing has also been found to facilitate learning, since it reduces cognitive load due to embodied cognition related effects. Goldin-Meadow et al. [29] found that both adults and children were able to remember a significantly more extensive list of letters and words as they gestured while solving a math problem compared to the groups that did not gesture. Additionally, Valenzeno et al. [30] found that preschool children who studied an instructional animation on symmetry containing both narration and observation of teachers' gestures outperformed the children in the narration-only

group. Cook et al. [31] asked children to view a computer avatar providing instruction for mathematics either with or without gestures. Children who viewed the gesturing avatar were found to learn and solve problems quicker. Hence, there is evidence that learning performance can be improved with the use of gestures, as it is an embodied cognition strategy that has successfully been used to support learning.

Benefits associated with mimicking have also been found in diverse domains, including dance [32], guitar playing [17], and vocabulary learning [3,33,34]. Learning to play musical instruments can involve making meaningful imitative gestures relevant to the task at hand. Mierowsky et al. [7] explored the effect of mimicking gestures on learning to play musical scores on the piano. For novices, it was found that mimicking gestures led to greater performance while playing the easy and medium musical pieces, whereas for more experienced learners, gesturing was beneficial for the more difficult pieces (since gesturing was found to be redundant for the easy and medium pieces). Hence, mimicking gestures of how to perform a task can be used to enhance the learning process due to embodied cognition-related benefits.

1.3. Practice

Practice during learning can help support the recall of new information and the automation of new skills, which can free up cognitive resources to deal with more demanding tasks [35]. Practice plays a major role in how well we learn and acquire expertise [36]. It does not simply involve repeating a task but also focuses on attention, rehearsal, and repetition, which can lead to new knowledge acquisition that can be a starting point for more complex learning. Practice has been found to have positive effects on performance in various fields that involve both motor and cognitive skill acquisition, such as chess and music [37–39]. Practice can be a form of embodied cognition when it involves direct tactile interaction with the learning task at hand, e.g., playing the piano or creating origami while learning how to complete the tasks, or when it involves imitating or mimicking the task at hand, e.g., writing a character in the air.

Various practice types have been incorporated to assess their impact on learning. Of interest to the present study is the comparison of real and imitative practice. McBride and Rothstein [5] explored the benefits of real physical versus mental practice and a combination of both when learning to use a paddle to hit a golf ball to a target. They found that all forms of practice led to improved skill accuracy, with combined practice being best, followed by physical practice and mental practice, respectively. Their study supports the benefits of all types of practice when learning motor skills, with real benefits associated with real physical practice. De Stefani et al. [4] found benefits associated with observational imitative learning (where participants observed performance by an expert athlete) for young children when learning new sports actions when compared to descriptive learning that was integrated with static images. Hence, the studies described above demonstrate that physical, mental, and observational forms of practice have all been found to be effective for supporting the learning of motor skills.

1.4. Present Study

The present study investigates the impact of practice type on learning from instructional animations. The study comprises two experiments, with each focusing on a different hand motor-based task—piano playing (Experiment 1) and paper folding (Experiment 2). The overarching research question of the study is: How do real and imitative practices compare to no practice in terms of learning performance, efficiency, and cognitive load in the observational learning of these two tasks? This research question has been broken down into the following sub-topics:

- Learning Performance—How do real practice and imitative practice differ in terms of learning outcomes compared to no practice?
- Cognitive Load—How do real practice and imitative practice differ in terms of cognitive load compared to no practice?

- Learning Efficiency—How do real practice and imitative practice differ in terms of learning efficiency compared to no practice?
- Impact of Learning Task—Does the type of task, e.g., varying the sensory modality involved, influence the effectiveness of different practice types?

The study, consisting of two experiments, explores different types of practice while learning from instructional animations. The first experiment involves the hand motor task of piano playing, and the second uses a different hand motor task of paper folding. The impact of physically interacting with an object (real practice) versus using mimicking gestures (imitative practice) or no practice (observational only) while learning is explored in both experiments. Experiment 1 involves pressing keys on the keyboard for real practice (with no sound) and air piano playing for imitative practice. Experiment 2 involves folding the origami paper for real practice and simulating the paper folding hand actions for imitative practice. We explore tasks that included the mediums of audio and tactile (piano playing) and just tactile (origami) to observe whether similar or different effects were observed. Building on Experiment 1, Experiment 2 additionally considers the impact of gender and spatial ability on the different interventions.

As discussed earlier, instructional animations, when incorporating practice, have demonstrated the potential to enhance learning outcomes. We test a series of hypotheses across the two experiments, with the expectation that practice will support learning. Since real practice involves direct physical engagement with the task, it is hypothesized to lead to better learning performance with greater activation of the mirror neuron system [17]. By becoming more familiar with the tasks, learners are expected to have a reduced cognitive load, which is further expected to translate into greater learning efficiency, meaning the amount of learning achieved relative to invested cognitive load [40]. Accordingly, the following hypotheses were developed:

Hypothesis 1a. *Real practice will lead to better learning performance than no practice.*

Hypothesis 1b. *Real practice will lead to less cognitive load than no practice.*

Hypothesis 1c. *Real practice will lead to greater learning efficiency than no practice.*

The impact of imitative practice compared to no practice is also explored. Since imitative practice involves mentally rehearsing the task by mimicking actions, it is expected to also provide benefits in terms of learning performance and efficiency, with reduced cognitive load.

Hypothesis 2a. *Imitative practice will lead to better learning performance than no practice.*

Hypothesis 2b. *Imitative practice will lead to less cognitive load than no practice.*

Hypothesis 2c. *Imitative practice will lead to greater learning efficiency than no practice.*

We are also interested in the open research question of whether there are any learning differences between real and imitative practices for different learning content and under different learning conditions. Real practice, which involves physical engagement with the task, is expected to activate the mirror neuron system more effectively than imitative practice, leading to better learning performance.

2. Experiment 1

The first experiment used the same instructional materials as Mierowsky et al. [7], where they explored the effect of gesturing while learning different piano scores. Mierowsky et al. [7] found differences in benefits of mimicking gestures to support learning; the gestures were most useful when the instructional content was of a moderate level of difficulty, as per

level of expertise. For the experts, for the easier tasks, the gestures were redundant, but for the more complex tasks, they were beneficial. In contrast, for novices, for the easier tasks, the gestures supported learning, while for the very complex tasks, they potentially became overwhelming. In Experiment 1, all three groups observed video recordings. However, one group was observational learning only (no practice), the second group engaged in imitative practice (gesturing in the air), and the third group participated in real practice (pressing on the keyboard with the sound off).

Since this first experiment involved tasks with differing levels of difficulty, we expected to see potential interactions among the three groups consistent with Mierowsky et al. [7].

2.1. Method

2.1.1. Participants

Sixty university students (38 females, 22 males) between the ages of 18–44 were recruited to participate. A questionnaire was given to participants before the instructional phase to determine their experience level in playing the piano. At least one year of musical experience was required to be included in the study, including some piano playing experience. The level of musical expertise self-reported by participants was used to allocate participants equally across the three groups (imitative practice, real practice, and no practice), with 20 in each group.

2.1.2. Materials

2.1.2.1. Learning Materials

The instructional content for this experiment consisted of a series of piano-playing clips of varying difficulty. Six short video clips of hands playing the piano, accompanied by audio, were included. Two of these clips were practice clips provided to familiarize participants with the format of the videos.

The video clips were designed by Mierowsky et al. [7], with a focus on the clips being both a manageable length and tailored for a range of musical expertise levels. Since the information was transitory and there was no user control when watching the video clips, it was essential to ensure that the amount of transitory visual and auditory information presented was digestible. The difficulty of the pieces was set to avoid a floor or a ceiling effect (i.e., making it too easy or hard). Lengths and difficulty levels were decided based on the results of testing conducted by Mierowsky et al. [7].

The clips varied in difficulty, with Clip 1 being easy (consisting of a single hand playing for 10 s), Clip 2 (easy–medium), Clip 3 (medium–difficult), and Clip 4 (difficult), which consisted of one hand playing for 15 s. The clips were developed by Mierowsky et al. [7] using a Canon EOS-M digital camera on a tripod and a Casio Privia PX-330 electric piano.

Musical tenets such as phrasing, intervals, chords, and cadences enable musicians to remember, recall, or predict musical information accurately. Clips 2 and 3 take advantage of these elements, with some notes being played simultaneously in recognizable chords and intervals. Clip 4, however, does not rely on these musical characteristics and instead presents a series of individual notes that make little musical sense. Although Clip 4 is played with only one hand and might appear to be less challenging than Clips 2 and 3, it was found to be more difficult when considered through a musical lens.

All participants were presented with the same material in the same order using a Gigabyte P34G v2 14-inch laptop.

2.1.2.2. Cognitive Load Measures

To obtain a measure of cognitive load, subjective difficulty rating scale measures were used, adapted from Paas [41]. The Likert scale questions included “Please indicate how easy or difficult it was for you to understand the learning material” and “Please indicate how easy or difficult it was for you to play back the musical phrase”. The questions were followed by a 9-point Likert scale, with ratings ranging from “1—Extremely easy” to “9—Extremely difficult”.

2.1.3. Procedure

Each participant was welcomed, signed the consent form, and was briefed about the study's requirements. They were asked to watch each clip four times with a 3 s break between each viewing. Participants in the no practice group were instructed to place their hands flat on the table in front of them while watching the clips to prevent them from gesturing. Participants in the practice groups were asked to place their hands flat on the table for the first two viewings and then imitate the hand movements seen for their third and fourth viewing. Those in the imitative practice group gestured in the air as though playing the piano along with the clips, without tactile feedback. Participants in the real practice group pressed on the keyboard with the sound switched off, mimicking playing along with the clips. After viewing each clip four times, participants were asked to rate the learning difficulty on the Likert scale. They then entered the testing phase, where they were asked to play the musical piece they learned on a keyboard provided, with the audio turned on. After playing the piece, participants were asked to rate the testing difficulty on the Likert scale. Participants were thanked, and a $20 gift voucher was given upon completion of the experiment.

2.1.4. Scoring Participants

The Levenshtein distance D was used to measure the difference between the correct music sequence and the music sequence performed by the participant [42]. Additionally, idle time, T, i.e., time taken to think and process the musical phrase, was accounted for. The performance score was calculated by deducting the sum of idle time T and Levenshtein distance D from the maximum score M as follows:

$$\text{Performance} = \max(M - (D + \min(T, 4)), 0). \quad (1)$$

The efficiency metric combined both cognitive load and task performance to consider the cognitive costs of learning [40]. Standardized scores for performance and cognitive load, Z, were considered to calculate the relative efficiency of the instructional conditions as follows:

$$\text{Efficiency} = \frac{Z_{\text{Performance}} - Z_{\text{Cognitive Load}}}{\sqrt{2}}. \quad (2)$$

2.2. Results

2.2.1. Performance Scores

A one-way repeated measures ANOVA was conducted on performance scores for the four different piano clips (mean scores shown in Table 1).

Table 1. Mean performance scores and standard deviations for different practice conditions and clips.

Condition	Clip 1	Clip 2	Clip 3	Clip 4	Combined Clips
Real practice	72.8 (33.6)	70.2 (29.1)	65.9 (34.5)	69.0 (20.0)	69.5 (29.3)
Imitative practice	83.3 (23.0)	85.0 (19.5)	74.7 (26.9)	70.0 (19.7)	78.3 (22.3)
No practice	70.2 (31.1)	70.1 (29.9)	54.4 (33.8)	54.7 (23.8)	62.4 (29.7)
Combined conditions	75.4 (29.2)	75.1 (26.2)	65.0 (31.7)	64.6 (21.2)	70.0 (27.1)

Within-subjects effects: There was a significant within-subjects effect [$F(3, 171) = 5.4$, $p = 0.001$, $\eta_p^2 = 0.088$], indicating that performance varied over the musical clips, where participants scored lower on the last 2 clips.

Between-subjects effects: The between-subjects effects just failed to reach significance at the $p = 0.05$ level [$F(2, 57) = 2.76$, $p = 0.07$, $\eta_p^2 = 0.088$].

Interaction effects: There was no practice × musical clip interaction [$F < 1$].

2.2.2. Cognitive Load Measures

Within-subjects effects: There was a significant within-subjects effect for cognitive load measures [$F(3, 171) = 14.6$, $p < 0.001$, $\eta_p^2 = 0.20$], indicating variations over the 4 musical clips. As can be seen from Table 2, participants found the later musical clips to be more difficult than the earlier ones.

Table 2. Mean of cognitive load (max = 9) and standard deviations for all clips.

Condition	Clip 1	Clip 2	Clip 3	Clip 4	Combined Clips
Real practice	4.60 (1.67)	5.25 (1.74)	5.25 (1.99)	6.60 (1.47)	5.42 (1.72)
Imitative practice	3.90 (1.74)	5.05 (1.64)	5.10 (2.05)	6.15 (1.84)	5.05 (1.82)
No practice	4.90 (1.59)	5.45 (1.57)	6.10 (1.41)	7.30 (1.26)	5.94 (1.46)
Combined conditions	4.47 (1.70)	5.25 (1.63)	5.48 (1.86)	6.68 (1.52)	5.47 (1.67)

Between-subjects effects: The between-subjects effects for cognitive load just failed to reach significance at the $p = 0.05$ level [$F(2, 57) = 2.830$, $p = 0.067$, $\eta_p^2 = 0.090$]. Notably, the no practice condition encountered the greatest level of difficulty (see Table 2), consistent with the performance means (see Table 1).

Interaction effects: There was no practice × musical clip interaction for the cognitive load measure [$F < 1$].

2.2.3. Efficiency Measures

Mean efficiency scores are presented in Table 3.

Within-subjects effects: There were no significant differences in efficiency scores within subjects [$F < 1$].

Between-subjects effects: There was a significant difference between conditions for efficiency scores [$F(2, 57) = 3.92$, $p = 0.025$, $\eta_p^2 = 0.12$]. Follow-up Bonferroni post hoc tests indicated that the imitative practice group had significantly higher efficiency scores than the no practice group ($p = 0.021$). No other pair-wise comparisons were significant.

Interaction effects: There was no practice × musical clip interaction for the efficiency measure [$F < 1$].

Table 3. Mean efficiency scores and standard errors across all clips.

Condition	Clip 1	Clip 2	Clip 3	Clip 4	Combined Clips
Real practice	−0.118 (1.23)	−0.128 (1.24)	0.109 (1.22)	0.179 (0.998)	0.010 (0.200)
Imitative practice	0.424 (1.23)	0.345 (1.24)	0.356 (1.22)	0.412 (0.998)	0.380 (0.200)
No practice	−0.306 (1.23)	−0.217 (1.24)	−0.465 (1.22)	−0.591 (0.998)	−0.400 (0.200)

2.2.4. Exploratory Analysis

In the above analysis, only efficiency scores produced a significant difference between practice conditions. However, for both performance and cognitive load scores, there were near misses (both $p < 0.07$). Examination of Tables 1 and 2 suggests that there may be differences according to individual clips, even though interactions were not detected. Therefore, some exploration analyses (ANOVA and post hoc procedures) were conducted on individual clips. For Clips 1, 2, and 3, no significant differences were found. However, for Clip 4, significant differences were found between imitative practice and no practice, showing that imitative practice had greater performance and efficiency scores with less cognitive load than the no practice group. Furthermore, for this clip, the real practice group also had significantly higher performance scores than the no practice group.

Although this analysis is exploratory in nature, some weak evidence emerged that the imitative practice condition had the most benefits for the musical clip with the highest difficulty to perform.

2.3. Discussion

Both hypotheses were tested in this experiment. While the type of practice had no significant effect on performance or cognitive load measures overall, some significant differences were observed as the video clips became more difficult. Participants who used imitative practice in the third (medium–difficult) and fourth (difficult) clips experienced greater performance scores than those who did not practice. Imitative practice in the fourth clip also resulted in lower cognitive load scores compared to no practice. Additionally, real practice in the fourth clip resulted in higher performance scores than no practice. Significant results were also observed in the efficiency scores across all clips. Participants who used imitative practice during the learning process experienced greater efficiency than no practice.

The overall ANOVAs across all four musical clips revealed that both real practice and imitative practice did not lead to greater learning or lower cognitive load than no practice, and therefore Hypotheses 1a, 1b, 2a, 2b could not be supported over the whole problem set. Hypothesis 2c was supported, as imitative practice was more efficient than no practice, but real practice was not more efficient than no practice, and therefore Hypothesis 1c was not supported. However, the exploratory analysis looking at individual musical clips suggests that the complexity of the clips may have moderated the effectiveness of the practice groups. This evidence suggests that, on the most difficult clip (fourth), imitative practice led to greater performance and efficiency, as well as lower cognitive load, than the no practice group. In addition, real practice had higher performance scores than the no practice group, suggesting that both practice forms were helpful.

Regarding the open question investigating differences between the two practice conditions, the weak exploratory evidence for Clip 4 suggests that, for this learning topic, imitative practice was superior to no practice only, suggesting an advantage for imitation.

3. Experiment 2

In Experiment 1, some significant differences were found in favor of imitative practice over no practice, but not for real practice. Hence, it remained to be seen whether the effects of real and imitative practice would differ in a different task requiring different sensory mediums. Thus, Experiment 2 was completed using a different movement-based learning task of paper folding. In the present study, spatial ability and gender have also been considered, as both factors have been found to influence performance in spatial-based motor tasks [1,2,43]. The spatial ability of an individual indicates their capacity to interact with and manipulate visual input [43]. Past research suggests that gender differences in spatial ability and learning exist [12,44–46] and are affected by various factors, including the type of visualizations used to measure learning and spatial ability. In particular, spatial ability has been found to be higher in males compared to females [47–49], with a meta-analysis conducted by Linn and Petersen [45] suggesting that gender differences arise on some types of spatial ability but not others, with the largest difference being found on measures of mental rotation and smaller differences found on measures of spatial perception. Moreover, research into the neuroanatomy of the human mirror neuron system supports potential gender differences, since females make use of mirror neurons (which fire when an action is observed and then recreated) to a greater degree compared to males [50–55].

3.1. Method

3.1.1. Participants

Sixty university students (30 females, 30 males) between the ages of 18 and 35 were recruited as participants. An online screening test was used to assess paper folding experience and collect demographic characteristics such as age and gender. Only participants with no experience or very limited paper folding experience were deemed eligible to participate. The participants were equally divided into three groups: imitative practice, where they were required to gesture hand movements in the air; real practice, where they completed

the actual paper folding task; and no practice. There were 20 participants in each group (F = 10, M = 10).

3.1.2. Materials

3.1.2.1. Learning Materials

Pilot trials were conducted on Wong et al.'s [8] animation materials to fine-tune the difficulty level of the paper folding tasks to avoid both ceiling and floor effects. Based on the findings of the pilot trials, the pace of the video was increased to 120%, speeding it up by approximately 40 s to prevent ceiling effects.

3.1.2.2. Cognitive Load Measures

Mental effort is an aspect of cognitive load that focuses on the cognitive capacity allocated by the learner to cater to the learning demands of a task and hence can be used to measure cognitive load [56]. As in the previous experiment, scales were adapted from Paas [18] and used to assess participants' perceived cognitive load levels after learning and completing the task. Unlike the previous experiment, the term 'mental effort' was used in the survey instead of 'difficulty' to attempt to more accurately reflect the cognitive resources invested by learners, and perhaps to then find significant differences in subjective ratings. De Leeuw and Mayer [57] found that mental effort is related to germane load, which relates to the cognitive resources contributing to learning, while task difficulty is more associated with intrinsic load, which is associated with the complexity of the learning material. This revised choice of wording was further validated with pilot testing.

3.1.2.3. Spatial Ability Test

A common measure of spatial ability is the Punched Holes Test [58]. It has been demonstrated that it is psychometrically reliable and significantly correlated with measures of executive functioning and working memory limitations [59,60]. Hence, the Punched Holes Spatial Ability Test was administered as a measure of spatial ability. It was administered as a two-part test, with 10 multiple choice questions in each part. For each question, participants were presented with an image of a paper being folded with a hole punched through it. They were given five options to correctly identify what the paper would look like when unfolded.

3.1.3. Procedure

Each participant was welcomed, signed the consent form, and was briefed about the study's requirements. They were then asked to complete the Punched Holes Test, which consisted of two parts, with three minutes given for each part, after receiving a verbal explanation of the task along with a sample question. Participants viewed the paper folding animation twice. In the no practice group, participants were asked to keep their hands on the table in front of them during both viewings to avoid any hand movements. For both practice groups, participants were asked to place their hands flat on the table in front of them during the first viewing. The real practice group was asked to complete the paper folding task using provided origami paper while watching the animation for the second time. The imitative practice group was briefed with four examples of meaningful hand gestures and then asked to mimic the hand movements of the task using mimicking gestures while watching the animation for the second time. Afterward, participants completed a post learning questionnaire to assess their mental effort during learning. They then entered the testing phase, where they were asked to complete the paper folding task in five minutes. Their hand movements were recorded using an iPhone camera placed on a desk-level tripod. Following the completion of the task, participants were asked to complete a post test questionnaire to assess their mental effort during the task. Participants were thanked and given a $20 gift voucher upon completion of the experiment.

3.1.4. Scoring Participants

Wong et al.'s [8] marking criteria were revised to score the performance of participants. One mark was awarded for the correct completion of each of the 27 steps in the criteria, with a maximum possible score of 27/27. Since most participants were able to complete the task within the time limit, except for 10 participants, the scoring method aimed to differentiate participants who found it easier to complete the task compared to those who found it more difficult. Half a mark was deducted if a particular step was completed differently, was completed in the wrong direction, or if an extra step was added.

As with Experiment 1, efficiency was calculated to consider the cognitive costs of completing the task as follows:

$$\text{Efficiency} = \frac{Z_{\text{Performance}} - Z_{\text{Cognitive Load}}}{\sqrt{2}} \quad (3)$$

3.2. Results

3.2.1. Spatial Ability Scores

There was no significant difference between males (M = 59.5) and females (F = 56.8), $t(58) = 0.68$, $p = 0.50$.

3.2.2. Performance Measures

The mean performance scores (covariate-adjusted) and standard errors are reported in Table 4. Because of equal gender distributions, a 2-way ANCOVA with a factorial design of 3 (practice condition: real practice, imitative practice, no practice) × 2 (gender: female, male) was conducted, with the Punched Holes Test scores used as a covariate to control for spatial ability.

Table 4. Adjusted mean of performance (max = 100) and standard errors for females and males.

Condition	Overall	Females	Males
Real practice	65.2 (3.21)	70.3 (4.2)	58.8 (4.16)
Imitative practice	62.4 (3.21)	70.0 (4.2)	56.1 (4.17)
No practice	52.0 (3.19)	43.3 (4.9)	60.8 (4.94)

The 2-way ANCOVA found a main effect for performance scores [$F(2, 53) = 4.72$, $p = 0.013$]. Follow-up Bonferroni post hoc tests showed significantly higher performance in real practice compared to no practice ($p = 0.016$), but no significant difference was found between imitative and no practice ($p = 0.08$) or between real and imitative practice ($p > 0.10$).

There was no gender main effect ($F < 1$), but there was a significant interaction between practice conditions and gender [$F(2, 53) = 8.015$, $p = 0.001$]. To investigate this interaction (see Figure 1), follow-up analyses were completed for each gender. A one-way ANCOVA revealed a significant main effect on practice types for the performance of females [$F(2, 26) = 16.8$, $p < 0.01$]. Bonferroni post hoc tests demonstrated significantly higher performance in real practice compared to no practice ($p < 0.01$) and for imitative practice compared to no practice ($p < 0.001$), but no significant difference between real practice and imitative practice. There was no significant main effect across conditions for males ($F < 1$). However, it is interesting to further note that males scored greater than females ($p < 0.05$) when no practice was involved, but less than females for imitative practice ($p < 0.05$) (see Figure 1).

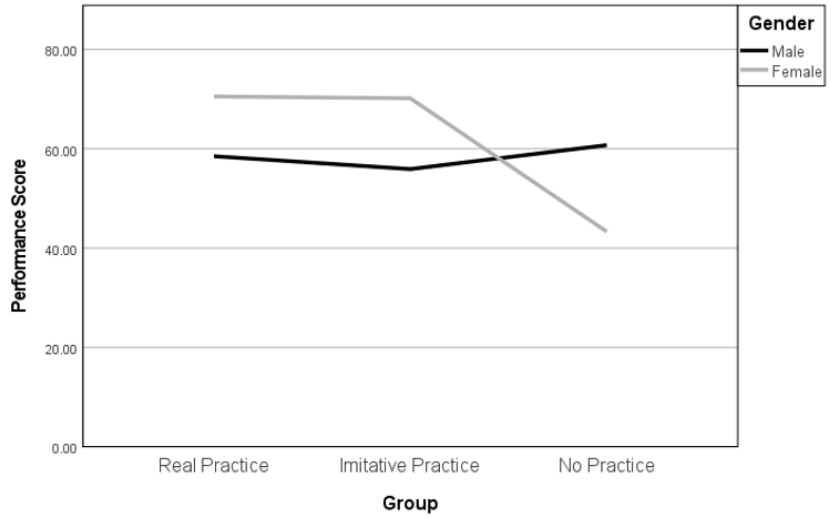

Figure 1. Performance mean scores (out out 100) across conditions for gender.

3.2.3. Cognitive Load Measures

The cognitive load mean scores (and SD) were 5.4 (1.4), 5.6 (1.8), and 5.4 (1.3) for real practice, imitative practice, and no practice, respectively. No significant main effects were found for practice condition and gender, nor was there a significant interaction (all $F < 1$).

3.2.4. Efficiency Measures

The mean efficiency-adjusted scores are presented in Table 5 and Figure 2. The ANCOVA test did not demonstrate a significant effect for practice conditions [$F(2, 53) = 0.771$, $p = 0.467$] or gender [$F(1, 53) = 0.146$, $p = 0.704$]; however, a significant interaction was found between practice conditions and gender [$F(2, 53) = 3.56$, $p = 0.035$]. To investigate this interaction, a one-way ANCOVA revealed a significant main effect for females across the practice types [$F(2, 26) = 4.92$, $p = 0.015$]. Bonferroni post hoc tests demonstrated real practice to be significantly more efficient than no practice ($p = 0.033$) and imitative practice to be significantly more efficient than no practice ($p = 0.041$). No significant main effect was found for the efficiency scores of males among the conditions using the ANCOVA test [$F < 1$]. Furthermore, when comparing males and females, no significant differences in efficiency were found across the practice conditions.

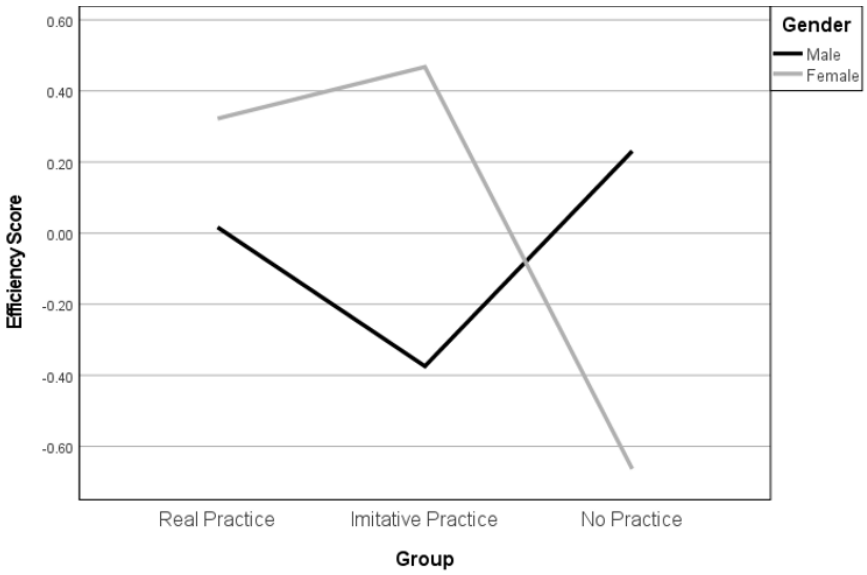

Figure 2. Efficiency mean scores across conditions for gender.

Table 5. Adjusted efficiency scores and standard errors.

Condition	Overall	Females	Males
Real practice	0.204 (0.240)	0.401 (0.343)	0.006 (0.338)
Imitative practice	0.012 (0.240)	0.426 (0.339)	−0.401 (0.338)
No practice	−0.216 (0.239)	−0.688 (0.338)	0.236 (0.338)

3.3. Discussion

Both broad hypotheses were tested in this experiment. Hypothesis 1a was supported, as real practice was superior to no practice for test performance, but not Hypothesis 2a, as imitative practice did not show any overall advantage over no practice (although it was supported for females). Hypotheses 1b and 2b were not supported, as no significant differences were found on the cognitive load measures. Hypotheses 1c and 2c were supported, but only for female learners, who demonstrated that both real and imitative practice were more efficient than no practice. For males, no significant differences were found for efficiency across conditions. Interestingly, no differences were found between males and females regarding the aspect of spatial ability measured, suggesting that spatial ability was not a factor in the gender interaction.

Controlling for spatial ability and gender allowed for an investigation of gender, where we found some significant gender effects, where females were found to learn best with both real and imitative practice, and no difference was found among practice conditions for males. Moreover, females learned more efficiently with both real and imitative practice than no practice, and there were no differences for males. In addition, the performance of females was significantly disadvantaged when learning with no practice in comparison to males (males performed significantly better without practice).

Regarding the open question, comparisons between the two practice conditions slightly favored real practice, as it demonstrated a clear test performance advantage over no practice for the whole sample, a benefit not shown by the imitative condition. However, when gender was considered, imitative practice was more advantageous for females than for males.

4. General Discussion

The two experiments aimed to compare different types of practice and their relative effectiveness at improving performance and learning efficiency while reducing cognitive load. The tasks in both experiments were from different disciplines and were human movement-based, with Experiment 1 focusing on piano playing and Experiment 2 on paper folding.

Experiment 1 demonstrated imitative practice to be superior, whereas real practice was superior for Experiment 2. In Experiment 1, imitative practice led to significantly increased learning efficiency compared to no practice, with the most difficult clip also having significantly improved performance and reduced cognitive load. In Experiment 2, real practice significantly enhanced learning performance and learning efficiency compared to no practice, although it did not reduce cognitive load. Females learned best from both real and imitative practice, and males performed better than females without practice.

Furthermore, gender differences were found in Experiment 2, where females were found to learn better and more efficiently using both real and imitative practice, with no differences for males. When comparing gender within practice types, females performed significantly better than males with imitative practice, and males performed significantly better than females with no practice.

Regarding the open question investigating differences between the two practice conditions, mixed results were found, with real practice leading to better learning for the paper folding task overall. Imitative practice led to better learning efficiency for piano playing and better performance for females compared to males for the paper folding task.

It appears that the type of practice that leads to better learning and efficiency is moderated by task complexity and gender-related effects.

While the interaction between culture and cognition has evolved significantly [61,62], making it a worthwhile dimension to consider when conducting this type of research, it was not the focus of these studies. Rather, we collected our data in a large western university. However, it is worth noting that our study did include participants of various nationalities, including some from Asia, Europe, and North America, which may reduce the potential cultural biases of the data.

4.1. Theoretical and Instructional Implications

4.1.1. Embodied Gesturing and Practice

Consistent with past findings relating to instructional animations and embodied cognition-related effects [3,29,63], the current study found that practice with instructional animations contributes to better learning. Evidence emerged that participants in the real practice group (Experiment 2) and the imitative practice group (Experiment 1) demonstrated an enhanced ability to replicate the learned tasks compared to participants in the no practice condition, who solely relied on observational learning. However, in both experiments, overall performance scores for real practice were not found to differ significantly from imitative practice. Additionally, evidence emerged that the effectiveness of the type of practice depended on the learning task.

In Experiment 1, audio feedback during real practice was omitted to prevent interference with the animated video audio channel, potentially impacting the degree of task replication for piano playing. In fact, it may partially explain why imitative practice was superior to real practice for the difficult tasks, where the tactile feedback may have been redundant [64]. Moreover, for less experienced learners, the tactile feedback perhaps induced split attention, similar to Cerpa et al. [65], who found that, when learning a computer application, the introduction of physical practice too soon in a complex task can cause a split attention-type of effect, where the focus is shifted to the physical apparatus and thus reduces cognitive capacity for more cognitive aspects of the task [64]. In Experiment 2, which involved no audio channel, participants likely perceived real practice to be more meaningful than imitative practice because it replicated the task exactly as explained in the video. Overall, the findings align with past research, demonstrating the effectiveness of practice in enhancing learning across diverse domains, including sports and music [37,38].

4.1.2. Spatial Ability and Gender

In Experiment 2, females were found to perform better with practice than with no practice (with a significant improvement in the performance and efficiency scores for both real and imitative practice), while there were no differences among practice types for males. When comparing genders for each practice type, males were found to perform significantly better with no practice, whereas females were found to perform significantly better with imitative practice. Wong et al.[12] found a similar gender interaction effect in a Lego-based learning task that incorporated practice during learning through instructional animations. Based on these results, it can be suggested that the absence of embodied practice may hinder the learning of females, while the inclusion of practice benefits females more than males. This implies that there may be underlying mechanisms that contribute to differences in how males and females learn, potentially related to greater mirror neuron activity in females [51–55,66].

Wong et al. [12] also tested for the correlation between spatial ability and gender; however, they were not able to attribute the significant gender interactions to spatial ability, since a significant correlation effect was not found. Halpern and Collaer [67] also found that paper folding tests of spatial ability did not demonstrate a link with gender differences. In these studies, it is possible that the relevant spatial ability construct may not have been captured accurately, using the most appropriate measurements. The Mental Rotations Test [68] is a common validated measure of spatial ability [46]. It can be explored in

combination with the Punched Holes Test and other validated measures of spatial ability. Given that this is the case and spatial ability is involved, a superior but unmeasured aspect of spatial ability could still be contributing to consistent performance for male participants across all three groups. The lack of some aspect of spatial ability in females may be introducing significant differences in the performance of females among the groups. It could also explain why females are disadvantaged when learning with observational learning only and may explain why embodied practice may help make up for the lack of spatial processing that may be required when only observing an animated video. The inclusion of new and different measures of spatial ability in future studies could thus be relevant, in order to try and ascertain whether different and yet unmeasured aspects of spatial ability may be contributing to gender differences.

Learning how to complete a movement-based task with the incorporation of practice may involve a variety of mechanisms that contribute to gender differences [69]. In particular, females have been found to be significantly disadvantaged when it comes to visuospatial memory [70]. Lower visuospatial memory is compensated for by the use of more gestures [71,72]. Hence, it is likely that females engaged in more embodied practice, leading to better results.

4.2. Limitations and Recommendations for Future Research

Experiment 1 was conducted on university-aged students, and it would be useful to explore if results can be replicated within other age groups, including children. Future studies could test different age groups using similar materials to examine whether similar results are seen across different age groups. While the focus was on different levels of complexity of instructional content and gender was not considered, it would also be useful to explore gender differences in these types of materials as well.

In Experiment 2, it would also be useful to explore if these results persist with different age groups. Moreover, it is possible that the spatial ability construct may have not been fully captured through the Punched Holes Test. The Mental Rotation Test is a spatial ability test that has been found to have the largest difference between scores for females and males [45,46]. Utilizing a range of spatial ability tests, including the Mental Rotation Test, may be needed to reflect the spatial ability differences more accurately between females and males. Piloting the correlation between the scores on a range of spatial ability tests and performance may be helpful in determining the type of spatial ability test to utilize in follow-up studies.

It is interesting to consider whether the advantages of embodied practice while learning human motor tasks from animations may persist over time. Cook et al. [73] found similar results from gesturing and non-gesturing groups, with improved performance only emerging post test. The present work could be expanded to include a delayed post test to assess whether the same effects persist long-term.

Although some interesting trends have been observed about gender when it comes to learning through instructional animations [12], there is not a lot of research to understand the reasons for these gender differences. Gupta et al. [69] found differences in instructional support needed for learning from instructional animations across genders, with females needing the extra support and males learning best from observational learning only, as well as finding that including spatial ability as a covariate impacted results. The second experiment has been successful in suggesting a significant interaction between gender and learning content design, as well as potential impacts from spatial ability. It is important to note that the gender effects found were based on a smaller sample size and should be validated in future studies. This paves the way for more work to be done in various domains to further investigate these interactions and the reasons for these differences. It is possible that, in some contexts, females need more instructional support when learning from animations than males, and this is worth exploring in the future with different learning tasks.

Our study was conducted in a large western university with many international students and, while it may be problematic to generalize these results to all other populations, we note that our student population was multi-cultural. However, like most research conducted within one country, it may not always generalize to other cultures. Future studies could more specifically address differences in cultural and socioeconomic contexts impacting cognition and learning in non-western environments, by collecting data from a different student population, thereby better considering possible cultural influences on learning [62]. Collecting data from different socioeconomic and cultural contexts would thus further enhance the applicability and generalizability of these findings [74,75].

4.3. Conclusions

The efficacy of animations as an instructional format is often undermined by the transience of information presented, as well as the limitations of working memory. However, some of these limitations are reduced due to our innate ability to learn by observing human movement effects. The increasing accessibility of animated instructional resources in an e-learning setting necessitates the need for more research into techniques to increase their effectiveness. The present study investigated the impact of embodied practice on learning from video-based instructional animations in human movement-related domains through two different experiments and found some clear benefits of embodied practice in different learning domains and contexts. Results suggest that practice can support learning, but whether it needs to be real or imitative will depend on both the type of instructional content as well as the knowledge of the learners, with possible gender effects in support of females benefiting most from practice. The results of this study may be of value to educators, as they provide guidance on when and how to incorporate practice into learning from instructional animations. The results suggest that the type of practice selected should be based on both the learning domain and learner characteristics. Educators can thus use these insights to make informed decisions that facilitate learning outcomes.

Author Contributions: Conceptualization: H.B. (Experiment 1), M.N.M. (Experiment 2), N.M., and P.A.; Methodology: H.B. and M.N.M.; Formal analysis: H.B., M.N.M., N.M., and P.A.; Investigation: H.B. and M.N.M.; Writing—original draft preparation: M.N.M.; Writing—review and editing: N.M. and P.A.; Supervision: N.M. and P.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of University of New South Wales (HC16138, March 2016 to March 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data can be obtained by contacting the first and second authors.

Conflicts of Interest: The authors declare no conflicts of interest.

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