Wong, M., Castro-Alonso, J. C., Ayres, P., & Paas, F. (2015). Gender Effects When Learning Manipulative Tasks From Instructional Animations and Static Presentations. *Educational Technology & Society, 18* (4), 37–52.

Gender Effects When Learning Manipulative Tasks From Instructional Animations and Static Presentations

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ABSTRACT

Humans have an evolved embodied cognition that equips them to deal easily with the natural movements of object manipulations. Hence, learning a manipulative task is generally more effective when watching animations that show natural motions of the task, rather than equivalent static pictures. The present study was completed to explore this research domain further by investigating the impact of gender on static and animation presentations. In two experiments, university students were randomly assigned to either a static or animation condition and watched a computer-controlled presentation of a Lego shape being built. After each of two presentations, students were required to reconstruct the task followed by a transfer task. In Experiment 1 the tasks were performed using real Lego bricks (physical environment), and in Experiment 2 by computerized images of the bricks (virtual environment). Results indicated no differences between the two testing environments or an overall advantage for the animated format. However, a number of interactions between gender and presentation format were found. Follow-up analyses indicated that females benefited more than males from using animated presentations.

Keywords

Animation vs. static picture, Gender differences, Embodied cognition, Cognitive load theory, Technology-based learning

Introduction to the study

Are static or animated instructional presentations better for student learning? The answer to this question is rather complex. The research literature comparing instructional statics with animations provides different perspectives, challenging a single conclusion. There are studies supporting the use of animations over static images (e.g., Ardac & Akaygun, 2005; Lin & Atkinson, 2011; Ryoo & Linn, 2012), but there is also contrasting evidence suggesting that statics are superior to dynamic visualizations (e.g., Castro-Alonso, Ayres, & Paas, 2014b; Mayer, Hegarty, Mayer, & Campbell, 2005; Scheiter, Gerjets, & Catrambone, 2006). Moreover, there are comparisons showing no statistical differences between statics and animations (e.g., Mayer, DeLeeuw, & Ayres, 2007; Narayanan & Hegarty, 2002). There are even concerns about the validity of some of these comparisons (see Tversky, Morrison, & Bétrancourt, 2002). There are, as observed by Höffler and Leutner (2007), a number of important moderating variables affecting the instructional effectiveness of static and dynamic visualizations. One such moderator, revealed in the meta-analysis of 26 studies by Höffler and Leutner (2007), was the type of task to be learned: Animations and videos were most effective, as compared to statics, when procedural-motor tasks were depicted.

Evidence also shows the importance of spatial ability when learning from static or dynamic visualizations (see Höffler, 2010). However, there is a lack of consensus indicating whether high or low spatial ability correlates favorably when learning from dynamic images. Furthermore, highly related to spatial ability issues are gender effects. Research has generally found that spatial ability is higher in males (see Linn & Petersen, 1985; Uttal et al., 2013; Voyer, Voyer, & Bryden, 1995), but there is also evidence accumulating that animated presentations are particularly helpful for females rather than males (see Sánchez & Wiley, 2010; Yezierski & Birk, 2006), which supports the hypothesis that low spatial ability students (females) benefit most from animations. But again to muddy the waters in this field, there is also evidence suggesting that male students can outperform females in animated conditions (see Lin, Hung, Chang, & Hung, 2014).

In view of these inconsistent results more research is required in this domain to identify the conditions impacting on the effectiveness of animations. The main aim of the current study was to make such a contribution by conducting two experiments comparing males with females when learning about object manipulative tasks, using both animated and static presentations. The following sections briefly outline the main theoretical aspects underpinning the investigation.

Instructional animations of manipulative tasks

As well as the meta-analysis of Höffler and Leutner (2007), some more recent studies have shown that animations and videos that show human motor tasks are more effective than equivalent statics. This has been reported for motor tasks such as unscrambling puzzle rings (Ayres, Marcus, Chan, & Qian, 2009), copying *origami* paper designs (Wong et al., 2009), or constructing different knots (Garland & Sánchez, 2013; Marcus, Cleary, Wong, & Ayres, 2013). Thus, when human movement is involved, animations (and videos) seem to be more effective instructional tools than static pictures. This finding has been termed the *human movement effect* (see Paas & Sweller, 2012), and can be explained by the fact that we evolved cognitive mechanisms to imitate tasks involving human motion (see also Castro-Alonso, Ayres, & Paas, 2014a).

In particular, humans have evolved an *embodied cognition* that links cognition to the environment through the body (see Barsalou, 2010). Classical cognitive accounts (e.g., Atkinson & Shiffrin, 1968) tended to isolate the mental processes from the rest of the bodily activities. In contrast, the embodied account connects the processes of mind, body, and environment (see Wilson, 2002). For example, when manipulating an object with the hands, the mind's mechanisms of observation and movement are linked with their corresponding body elements (eyes and hands) and with environmental cues (e.g., the object). The instructional implication of evolving an embodied cognition is that every visual learning task (perception) can be enhanced by bodily experiences (action). In consequence, the human movement effect is successful because it connects perception and action.

Restating, our cognitive system is wired towards linking perception to action. Arguably, the most important component to facilitate this connection is the *mirror neuron system* (also called the *observation-execution matching system*), composed of neurons that get activated both when observing and when imitating, for example, the manipulation of things (see Rizzolatti & Craighero, 2004). The first to describe this perception–action mechanism in humans were Fadiga, Fogassi, Pavesi, and Rizzolatti (1995), who found similar contractions in participants' hand muscles when the subjects either observed other humans doing hand movements or performed directly these actions. Having this mirror system implies that, when we watch an object being moved by human hands, we are preparing to eventually manipulate it ourselves. In consequence, the mirror neuron system greatly facilitates the imitation and learning of object manipulations (see van Gog, Paas, Marcus, Ayres, & Sweller, 2009).

As a result of having a system that allocates resources to deal with manipulative tasks (besides many other actions), learning to manipulate objects is a relatively easy task for humans. Further, object manipulation can be classified under *biologically primary abilities* in the framework of *evolutionary educational psychology* (see Geary, 2007; Geary, 2008). According to Geary (1995) biologically primary abilities have evolved with our species, allowing humans to survive and develop in their natural environment. Understanding body language, and imitating object manipulations are primary abilities that have helped our species to survive by communicating and accessing essential natural resources (Geary, 2000). Because these abilities have evolved and thus improved over many millennia, the human cognitive system is prepared to use them very efficiently, with relatively low effort. In contrast, the majority of tasks included in formal instruction, *biologically secondary abilities*, have not evolved to the same degree, and thus they can be difficult to attain (Geary, 1995). In consequence, educational institutions could use the easier primary abilities as vehicles to teach the harder secondary abilities (see Geary, 2008; Sweller, 2008). The current study followed this approach by using object manipulation (primary ability) to teach a sequence that led to the construction of a final shape (secondary ability).

In summary, when learning object manipulations, animations may be more effective than static pictures, because we have evolved to learn these primary tasks following natural movement. The fact that animations may be effective does not imply that there are equally effective for everyone. For instance, the influence of spatial ability is very important for the effectiveness of manipulative animations and static pictures.

Instructional visualizations and spatial ability

When learning from an instructional animation, learners are processing visuospatial input. Processing visuospatial information involves a high cognitive load on working memory processors (cf. Ayres & Paas, 2007; Baddeley, 1996; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). This cognitive capacity to manage visuospatial information can be termed as *spatial ability*. Because it is employed with any visuospatial input, spatial ability is also used when learning from other types of instructional visualizations, such as static pictures.

A wide variety of evidence shows the importance of spatial ability when learning from static or dynamic visualizations (see Höffler, 2010). However, there is a lack of consensus on whether spatial ability is better to learn from either static or dynamic images. For example, the meta-analysis of 27 experiments by Höffler (2010) showed that high spatial ability students were more advantaged than low ability students when learning from statics rather than from animations. Similarly, Sánchez and Wiley (2014) showed that the spatial ability of psychology undergraduates was more significant in learning from text supplemented with static images rather than with animated presentations. These results correspond to the *ability-as-compensator hypothesis* described by Mayer and Sims (1994). This explanation states that spatial ability is required more when learning from static pictures, as spatial ability permits *mental animation* (Hegarty & Sims, 1994). The static depictions thus *compensate* for the lack of motion in the visualizations. In contrast, Yang, Andre, Greenbowe, and Tibell (2003) found that high spatial ability undergraduates scored higher on a transfer test when learning from animations as compared to statics. According to Mayer and Sims (1994) this result would be evidence for the *ability-as-enhancer hypothesis*, in which spatial ability *enhances* the benefits of animations over static pictures.

In conclusion, it is evident that spatial ability is a key factor in learning from visualizations. What is less clear is whether spatial ability is more helpful when watching either static or animated images, although there is more evidence supporting its effects on static images, as Höffler and Leutner (2011) commented. As a result of the central importance of spatial ability in processing instructional visualizations, students with low spatial ability will be disadvantaged. This unfavorable situation is generally observed in females when compared to males.

Gender, spatial ability and animations

Research tends to agree that spatial ability is higher in males than females, particularly for a spatial sub-dimension called *mental rotation* (see Linn & Petersen, 1985; Uttal et al., 2013; Voyer, Voyer, & Bryden, 1995). Greater outcomes for males in spatial tasks have been consistently reported in a variety of contexts (e.g., Campbell & Collaer, 2009; Collins & Kimura, 1997; Feng, Spence, & Pratt, 2007; Law, Pellegrino, & Hunt, 1993; Masters, 1998; Voyer & Hou, 2006). Regarding gender effects of spatial ability on instructional visualizations, the evidence is less male oriented.

For example, the inconclusive direction of the effects of spatial ability on static vs. dynamic images is similarly inconsistent when incorporating the gender variable. There are studies showing that instructional animations are an advantage for both females and males. For example, Yezierski and Birk (2006) assessed the effectiveness of an animated intervention on middle school, high school and university students. The authors observed that the pre-test scores favoring males disappeared after the animation treatment, showing that the dynamic images helped to close the initial gender gap. In other words, females learned more than males with the animations. Also, Sánchez and Wiley (2010) reported that psychology undergraduate males outperformed females in both a spatial ability test and in learning from text passages on a science topic. However, learning was similar between genders when the passages also contained animations, showing that these dynamic images were especially helpful for females and low spatial ability students.

This first group of studies support the ability-as-compensator hypothesis (Mayer & Sims, 1994), where low spatial ability participants (generally women), are benefited from the animated depictions, as they do not need to mentally animate these visualizations. Regarding a second group of studies, where animations favor high spatial ability students (generally men), Griffin, MacEachren, Hardisty, Steiner, and Li (2006) observed that males had better performance following animated presentations rather than statics, and that females performed equally under both visualization conditions. Also Lin, Hung, Chang, and Hung (2014) showed that male university students outperformed females in the animated condition, but not in the condition presenting texts only. These two studies support the ability-as-enhancer hypothesis (Mayer & Sims, 1994).

As stated previously, it is not known which of the two hypotheses for spatial ability, either as compensator or as enhancer, is the most relevant when learning from instructional animations. Moreover, as far as we know, there are no studies addressing this issue for animations about object manipulative tasks. The present study aims to fill this gap in the literature.

General description and hypotheses of the current study

The current study compared the learning outcomes when imitating an object manipulative task after being modeled either in a static or animated presentation. In addition, gender effects were investigated. Consequently, a 2 (Presentation: static vs. animation) x 2 (Gender: male vs. female) between-subjects factorial design was used.

The manipulative task chosen was to complete a three-layered shape containing 15 Lego^{TM} Duplo^{TM} bricks of different lengths and colors based on the study by Castro-Alonso (2013). There was also a manipulative transfer task. In Experiment 1 all tasks were conducted physically, moving real Lego bricks with the hands. In contrast, in Experiment 2, the tasks were attempted in a virtual environment, moving Lego representations with the mouse. Previous results have shown that physical and virtual manipulations can yield equivalent outcomes (e.g., de Jong, Linn, & Zacharia, 2013; Zacharia & Olympiou, 2011). However, the *identical elements theory* (cf. Thorndike & Woodworth, 1901) and the *congruence principle for effective graphics* (Tversky et al., 2002) predict that doing the task in the physical environment may be more effective, as the presentations of this study involved real Lego bricks. Thus, by including two environments, we broadened the investigation, as well as providing opportunities for replication.

Two hypotheses were constructed. Because of the nature of the manipulative task a human movement effect was predicted in that animations would be superior to static presentations (Hypothesis 1). Castro-Alonso (2013) previously found support for this prediction with these same materials. The second hypothesis predicts a gender–presentation interaction. Even though research suggests that animation can favor both females and males, an interaction is likely considering the previous findings suggesting either males or females benefit most from animations. It was an open question as to which gender will benefit most in this study.

Hypothesis 1: Animations will be superior instructional materials to static pictures

Hypothesis 2: There will be a gender–presentation format interaction.

Experiment 1

The first experiment was conducted using a physical environment for testing.

Method

Participants

59 students (30 male, 29 female) aged between 17 and 40 (*M* = 22.5, *SD* = 5.29) were recruited from an urban Australian university. The sample consisted of 46 undergraduate students and 13 postgraduate students from various faculties including Arts and Social Sciences, Business, Engineering, Medicine and Science. They were randomly allocated into an animation group (16 male, 14 female) and a static pictures group (14 male, 15 female). Participants were given a $20 gift card for volunteering.

Materials

Background survey. This one-page questionnaire assessed gender, the university program, and the year that students were enrolled in, the level of study (i.e., postgraduate or undergraduate), and their handedness (right or left).

Assessment of spatial ability. To measure spatial ability, we employed the *Card Rotations Test* (Ekstrom, French, & Harman, 1976), which measures mental rotation of two-dimensional figures. Although the original test has two parts of 10 questions each, only the first part was used to maximize time for the experiment with a 3-minute completion allowance given.

Learning Materials. In the animation condition, a video depicting the 15 steps of a 3-D Lego construction (based on the materials used by Castro-Alonso, 2013) from an aerial view (see Figure 1) was filmed with a digital Sony Handycam in PAL standard (size 768 x 576 pixels; 25 frames per second) without audio. The video showed human hands (in green gloves) manipulating one Lego brick at a time, and placing them on a Lego platform one-by-one. The size of this animation was adjusted to a LEGO® platform’s size of approximately 200 x 200 pixels leaving the Lego platform placed at the center of the screen filled with white background. The video was then edited and exported with Adobe Premiere Pro CS3 (Adobe, 2007) to Adobe Flash Video format (.flv). In total, the animation lasted 92 seconds.

The video was resized to 200 x 200 pixel so that it was the same size as a single picture form the static picture condition (see Figure 1 left). Furthermore, a numbering system indicating the brick sequence was added onto the video to match with that in the static picture condition.

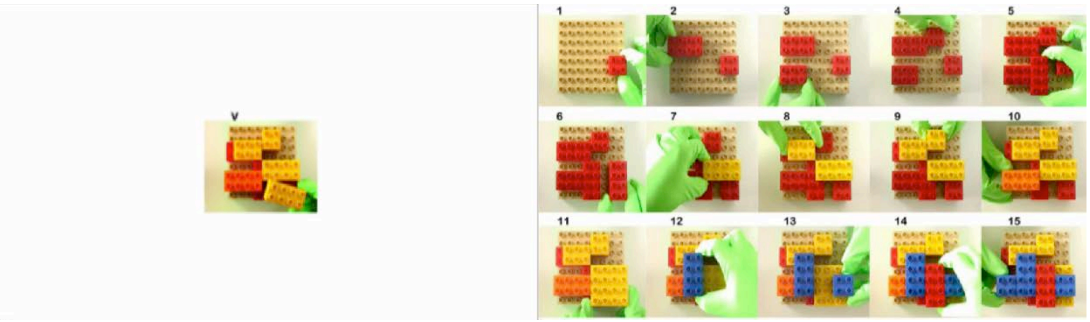

Figure 1. Experiment 1 animation condition (left) and static-picture condition (right)

In the static picture condition, 15 key frames showing each brick being placed was extracted from the animation. Each key frame had identical size and information as in the corresponding video (see Figure 1 right). All 15 frames, sequentially numbered on the top left, were presented simultaneously on the screen and could be viewed for the same time as in the animation presentation (92 seconds). It was important that every significant change (each brick placement) in the animation was also shown in the static condition, and that both presentation formats were sized identically. Extensive pilot testing of these materials suggested that no bias existed in favor of animation. In this fashion the concern expressed by Tversky et al. (2002) that animations often contain more information than statics was eliminated as much as possible.

For both animation and static conditions, participants had no control over the pacing of the learning materials.

Testing Environment

Completion Task. The same set of Lego Duplo bricks used in filming the learning material was used for testing. In this physical environment the actual bricks were given to the participants, arranged in a vertical position, according to the order that they appeared in the learning materials starting from top left to bottom right (see Figure 2). A brown square building platform was provided on their work desk for participants to build the required shape on. This platform had a fixed orientation identical to the learning presentation. Participants were required to build the shape they viewed in the presentation. They were told that the same set of bricks, in the same order, as shown in the presentation were given, and only one brick could be placed at a time starting from the top left to right bottom (See Figure 1). No changes were allowed once the previous brick position was confirmed and the next brick was picked.

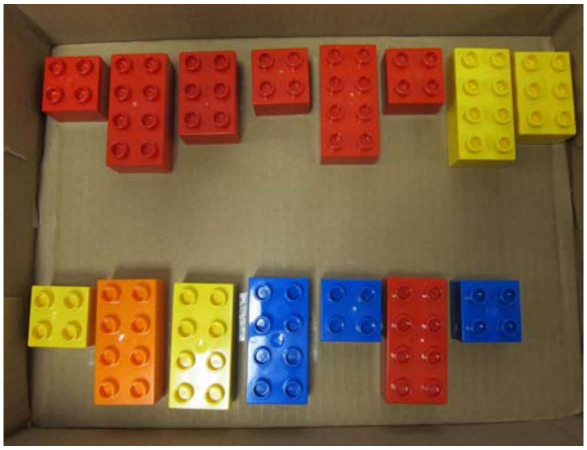

Figure 2. Performing environment used in completion task for Experiment 1

Transfer Task. The first six red Lego bricks, which were used in the completion task were reused in the transfer task. All 6 bricks were placed vertically and were arranged according to the order in the completion task starting from left to right (the six red bricks in the top line of Figure 2). Similar to the completion task, the square platform was provided as a basis for the building. For the transfer task participants were required to recall only the bottom layer (i.e., the first 6 bricks) from the learning material, but rebuild them in a 90-degree clockwise rotation. Participants were explicitly told not to rotate their heads nor the platform (which was fixed), instead, they were required to complete the rotation mentally.

Grading rubric. To ensure precise scoring of the tasks, a detailed grading rubric was developed. In completion tasks 1 and 2, one mark was given to each brick if the brick (same shape and color) was placed in its correct position regardless of the order in which it was placed. However, 1 mark was deducted if a) two or more adjacent bricks were placed in the correct position but were rotated; b) the bricks were place in the correct position and orientation, but the brick positions were switched; c) both orientation and configuration were correctly recalled, but the whole structure was shifted away from its correct position. Each level was scored separately – if a brick was placed in its correct position but on a different level, then no marks would be given for that brick. For the two completion tasks, the maximum score was 15 and the minimum was 0. In the transfer task, all the above rules applied. Additionally, 1 extra mark was given to those building with the correct (90 degree clockwise) correct configuration, sequence and orientation. The maximum score for the transfer task was 7 and the minimum was 0.

Self-report of cognitive load. To get a measure of cognitive load, a self-rating measure was used based on the subjective scale of Paas (see Paas, 1992; Paas & van Merriënboer, 1994). Participants were asked how much mental effort they spent in completing the task right after they completed each task. The responses were given on a 9-point Likert scale ranging from little (1) to fair (5) to heavy (9).

Procedure

The experiment sessions were conducted in a quiet room. Each session lasted about 40 minutes, and only one student was tested in each session. After completing the survey, the participants attempted the Card Rotations Test for 3 minutes. After a practice task, the participants watched the assigned learning task materials for the first time. Immediately afterwards they were required to build the shape (the 1st attempt). During this attempt participants had no access to the learning materials. Immediately after completion of their construction, they were required to rate their mental effort. This was then followed by a repetition of the procedure by watching the learning task for a second time and then attempting the construction (2nd attempt), and completing the mental effort scale. Immediately after the 2nd attempt of the main task, participants were given the transfer task followed by the mental effort rating of the transfer task.

Results

Tests of ANOVA assumptions

To test if the assumptions for using ANOVA were met, individual group normality tests (Kolmogorov-Smirnov) and Levene’s test for Homogeneity of variance were completed for all measures. The results indicated that all assumptions were met, and therefore ANOVA was used throughout this experiment.

Test of spatial differences

To test for initial spatial differences amongst the groups, the spatial measures (CRT test) collected before the acquisition phase were analyzed using a 2 x 2 ANOVA. The spatial measure (CRT scores) was not significant for gender ($F < 1$, *ns*), presentation type ($F < 1$, *ns*), or interaction ($F < 1$, *ns*). Hence, the CRT spatial measure was not used as a covariate and 2 (animation vs. static picture) × 2 (male vs. female) ANOVAs were used to investigate the hypotheses in this study.

Test scores

Group mean scores for each test (reconstruction attempts and the transfer test) score are reported in Table 1. Maximum scores for the 1st and 2nd attempts were 15, and the transfer test was 7.

Table 1. Means (*SD*) for test scores in Experiment 1

		Animation	Static picture	Total
Male	1st attempt	5.43 (3.52)	6.14 (3.44)	5.77 (3.44)
	2nd attempt	7.22 (4.55)	9.82 (4.51)	8.43 (4.64)
	Transfer	3.88 (2.60)	4.07 (2.75)	3.97 (2.63)
Female	1st attempt	7.00 (2.50)	5.43 (3.08)	6.19 (2.88)
	2nd attempt	10.75 (2.83)	8.80 (4.10)	9.74 (3.62)
	Transfer	5.18 (1.58)	3.63 (2.64)	4.38 (2.29)
Total	1st attempt	6.17 (3.13)	5.78 (3.22)	5.98 (3.16)
	2nd attempt	8.87 (4.19)	9.29 (4.25)	9.08 (4.19)
	Transfer	4.48 (2.25)	3.85 (2.65)	4.17 (2.46)

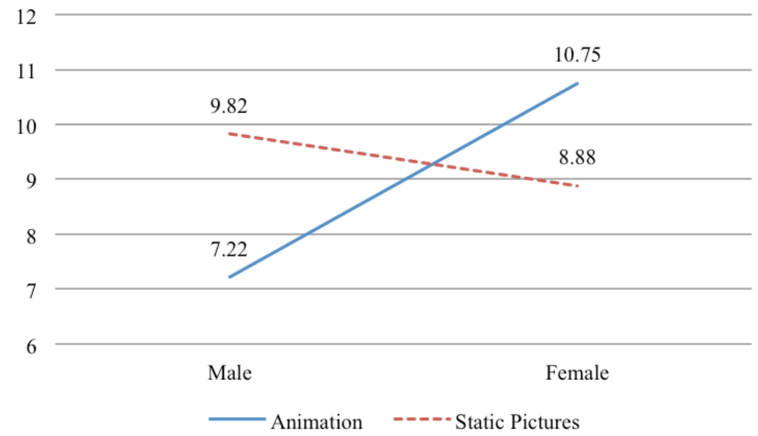

Figure 3. Completion interaction for the second attempt in Experiment 1

Two-way ANOVAs showed that there was no significant main animation effect for the 1st attempt (*F*< 1, *ns*); 2nd attempt (*F*< 1, *ns*); or the transfer task, *F*(1, 55) = 1.12, *p* = .30, *ηp2* = .02, *MSe* = 5.20. In addition, there was no significant main gender effect for the 1st attempt, (*F*< 1, *ns*); the 2nd attempt, *F*(1, 55) = 1.39, *p* = .24, *ηp2* = .03; or for the transfer task, (*F* < 1, *ns*). There was no significant interaction for the 1st attempt, *F*(1, 55) = 1.89, *p* = .18, *ηp2* = .03, or the transfer task *F*(1, 55) = 1.86, *p* = .18, *ηp2* = .03. However, there was a significant interaction for the 2nd attempt, *F*(1, 55) = 4.59, *p* = .04, *ηp2* = .08 (see Figure 3). Follow-up simple effects tests indicated that for the animation format, females (*M* = 10.75) scored significantly higher than males (*M* = 7.22); *F*(1, 28) = 6.28, *p* = .02, *ηp2* = .18. However for the static format, there was no significant gender difference (*F* < 1, *ns*).

Cognitive load scores

Group means scores for each cognitive load measure are reported in Table 2.

Table 2. Mean (*SD*) for cognitive load measure in Experiment 1

		Animation	Static picture	Total
Male	1st attempt	7.88 (1.5)	6.79 (1.93)	7.37 (1.77)
	2nd attempt	7.25 (1.65)	6.57 (1.83)	6.93 (1.74)
	Transfer	5.81 (2.23)	5.14 (2.48)	5.5 (2.33)
Female	1st attempt	8.00 (.88)	7.13 (1.25)	7.55 (1.15)
	2nd attempt	7.50 (1.16)	6.73 (1.44)	7.10 (1.35)
	Transfer	6.93 (1.82)	6.47 (2.42)	6.69 (2.12)
Total	1st attempt	7.93 (1.23)	6.97 (1.59)	7.46 (1.49)
	2nd attempt	7.37 (1.43)	6.66 (1.44)	7.02 (1.55)
	Transfer	6.33 (2.09)	5.83 (2.49)	6.08 (2.29)

Results indicated a significant main effect for presentation format for the 1st attempt, *F*(1, 55) = 6.80, *p* = .01, *ηp2* = .11, *MSe* = 2.07; where the participants in animation group (*M* = 7.94) rated cognitive load higher than in the static picture group (*M* = 6.96) ; a close to significance (*p* < .10) for the 2nd attempt, *F*(1, 55) = 3.23, *p* = .08, *ηp2* = .06, *MSe* = 2.38; where again the animation group (*M* = 7.38) reported higher cognitive load than static picture group (*M* = 6.65), but no significance for the transfer task (*F* < 1, *ns*). There were no significant gender effects at the first attempt (*F* < 1, *ns*), or the second attempt (*F* < 1, *ns*). For the transfer task, there was a significant gender effect, *F*(1, 55) = 4.32, *p* = .04, *ηp2* = .07, where females reported spending higher cognitive load (*M* = 6.69) than males (*M* = 5.47). There were no significant interactions (all *F* < 1, *ns*).

Discussion

There was no support for Hypothesis 1 that predicted an animation effect, as no evidence was found that animations were superior to statics on this task. The only significant effect was found for the cognitive load measure on the first attempt, where more cognitive load was recorded in the animation condition. A similar non-significant (*p* < .10) result was found at the second attempt. These results suggest that learning through animations required greater cognitive load, but this did not directly impact on performance. On the transfer task females reported higher mental effort than males, which again did not impact on learning.

Hypothesis 2 predicted a gender–presentation format interaction. On test scores there was a significant interaction for the second attempt at the task. Simple effects tests indicated that for the animation format females outperformed males, but for the static format no significant gender effects were found. Although, no other significant interactions were found for test scores, examination of Table 2 indicates that for both the first attempt and the transfer task, females had higher scores than males for the animated condition, but this pattern was not repeated for static presentations.

Experiment 2

As outlined in the introduction, Experiment 2 replicated the experimental design of Experiment 1 using a virtual testing platform instead of a physical testing platform. The same two hypotheses were again tested.

Method

Participants

86 students were recruited from a large university in Sydney (42 male, 44 female) participated in the experiment. They were enrolled in courses from various faculties including Arts and Social Sciences, Business, Engineering, Medicine and Science. The sample consisted of 72 undergraduate students and 14 postgraduate students, aged between 17 and 46 (M = 21.9, SD = 5.64). They were randomly allocated into four groups: animation (22 male, 22 female) and static pictures (20 male, 22 female).

Materials

The same learning materials and tasks from Experiment 1 were re-employed in Experiment 2. The only, and major, difference was the testing environment that participants built the Lego pattern onto. In contrast to Experiment 1, participants were required to rebuild the assigned pattern on a computer (virtual platform). The virtual platform (see Figure 4) was developed on Actionscript 3 with Adobe Flash CS4 Professional (Adobe, 2008). The same number and color of the bricks used in the learning and testing materials in Experiment 1 were created virtually. The participants were required to move the bricks and rebuild the Lego shape onto the square building-stage (shown in the top left of Figure 4). To reposition the bricks participants had to drag the bricks with the computer mouse, and double-click to rotate the bricks. Only one brick could be moved at a time. After participants had placed a brick, the next button needed to be clicked (shown in the top right of Figure 4) in order to move forward to the next brick. Moreover, once this button was clicked, no further modifications were possible. For the transfer task, the first six bricks used in the completion task were required. All six bricks were presented virtually and in identical order to the completion task starting from left to right.

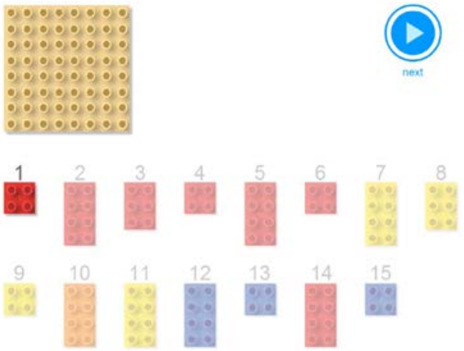

Figure 4. Performing environment of completion tasks in Experiment 2

Procedure

The same procedures and times (learning and testing) used in Experiment 1 were again followed. The only difference was that instead of the experimenter bringing the real physical bricks to the participants after they finished watching the learning materials, the building platform appeared automatically on the computer screen. There were three testing tasks: completion task 1 (1st attempt), completion task 2 (2nd attempt) and a transfer task. Cognitive load (mental effort) measures were collected after each task completion.

Results

Tests of ANOVA assumptions

Similar to Experiment 1 the Kolmogorov-Smirnov and Levene's tests were used to check that the assumptions for using ANOVA were met. All assumptions for the first and second completions were met; however, for the transfer task, the distribution of male scores in the animated format failed the normality test, $D(22) = .24$, $p = .002$, as did females in the animated format, $D(22) = .21$, $p = .011$. Furthermore, male transfer scores in the static format also failed the normality test. $D(20) = .39$, $p < .001$. There was a high proportion of students who achieved maximum scores, thus skewing the data. Hence, ANOVAs were used in the 1st and 2nd attempt of the completion tasks, and non-parametric methods were used in the transfer task analysis.

Test of spatial differences

To test for initial spatial differences amongst the groups, the spatial measures (CRT test) collected before the acquisition phase were analyzed using a 2 x 2 ANOVA. There was no main effect for gender, $F(1, 82) = 2.11$, $p = .15$, $\eta p2 = .03$; presentation type, $F(1,82) = 2.90$, $p = .09$, $\eta p2 = .03$; or a significant interaction, $F(1,82) = 1.11$, $p = .29$, $\eta p2 = .01$. Hence, the CRT spatial measure was not used as a covariate, and 2 (animation vs. static picture) × 2 (male vs. female) ANOVAs were again used to investigate the hypotheses in this study.

Test scores

Group mean scores for each test (reconstruction attempts and the transfer test) score are reported in Table 3. Maximum scores for the 1st and 2nd attempts were 15, and the transfer test was 7.

Table 3. Mean (*SD*) of performance in Experiment 2

		Animation	Static picture	Total
Male	1st attempt	6.23 (3.25)	6.63 (2.95)	6.42 (3.08)
	2nd attempt	9.84 (4.07)	11.33 (3.21)	10.55 (3.72)
	Transfer	5.00 (2.12)	5.65 (2.12)	5.31 (2.12)
Female	1st attempt	7.68 (1.82)	6.32 (2.55)	7.00 (2.30)
	2nd attempt	11.36 (2.30)	9.91 (3.48)	10.64 (3.00)
	Transfer	5.80 (1.41)	4.64 (2.13)	5.22 (1.88)
Total	1st attempt	6.96 (2.70)	6.46 (2.72)	6.72 (2.71)
	2nd attempt	10.60 (3.35)	10.58 (3.39)	10.59 (3.35)
	Transfer	5.40 (1.83)	5.12 (2.16)	5.26 (1.99)

The 2 (animation vs. static picture) × 2 (male vs. female) ANOVAs showed that there was no significant main animation effect for the 1st attempt ($F < 1$, *ns*) and the 2nd attempt ($F < 1$, *ns*). Likewise, there was also no significant main gender effect for the 1st attempt ($F < 1$, *ns*), and the 2nd attempt, ($F < 1$, *ns*). Also, there was no significant interaction for the 1st attempt $F(1, 82) = 2.30$, $p = .13$, $\eta p2 = .03$.

However, there were significant interactions for the 2nd attempt $F(1, 82) = 4.18$, $p < .05$, $\eta p2 = .05$ (see Figure 5). Follow-up simple effect tests showed no significant gender differences for the 2nd attempt in the animation format, $F(1, 42) = 2.34$, $p = 13$, $\eta p2 = 05$, $MSe = 10.91$, or the static format, $F(1, 42) = 1.87$, $p = .18$, $\eta p2 = .05$, $MSe = 11.25$.

Based on the previous interactions found, Mann-Whitney tests were conducted to examine potential gender simple effects. For animation, no significant differences was found between genders, $U(44) = 201.5$, $Z = -.99$, $p = .32$, $r = -.15$. However, for the static format, males (mean rank = 24.9) scored higher (significant at $p < .10$) than females (mean rank =18.41), $U(42) = 152.0$, $Z = -1.80$, $p = .07$, $r = -.28$.

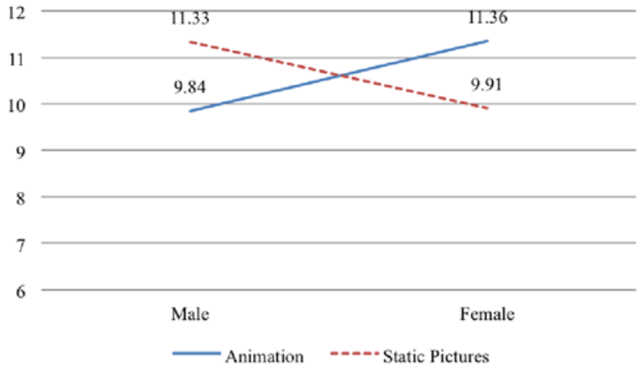

Figure 5. Completion interaction for the second attempt in Experiment 2

Cognitive load measure

Group mean scores for each cognitive load measure are reported in Table 4 respectively below.

Table 4. Mean (*SD*) for cognitive load measure in Experiment 2

		Animation	Static picture	Total
Male	1st attempt	7.77 (1.51)	7.10 (1.29)	7.45 (1.44)
	2nd attempt	6.91 (1.57)	6.25 (1.74)	6.60 (1.67)
	Transfer	6.09 (1.85)	5.15 (2.37)	5.64 (2.14)
Female	1st attempt	7.68 (1.00)	7.68 (1.09)	7.68 (1.03)
	2nd attempt	6.77 (1.11)	6.73 (1.52)	6.75 (1.31)
	Transfer	6.18 (2.26)	6.00 (2.05)	6.09 (2.13)
Total	1st attempt	7.73 (1.26)	7.40 (1.21)	7.57 (1.24)
	2nd attempt	6.84 (1.35)	6.50 (1.63)	6.67 (1.49)
	Transfer	6.14 (2.04)	5.60 (2.22)	5.87 (2.14)

Results indicated there was no significant main animation effect for the 1st attempt *F*(1, 82) = 1.59, *p* = .21, *ηp2* = .02, *MSe* = 1.53; for the 2nd attempt, *F*(1, 82) = 1.19, *p* = .28, *ηp2* = .01, *MSe* = 2.24; and for the transfer task, *F*(1, 82) = 1.45, *p* = .23, *ηp2* = .02, *MSe* = 4.56. Also, there was no significant main effect for gender for the 1st attempt (*F* < 1, *ns*), for the 2nd attempt (*F* < 1, *ns*), and for the transfer task, *F*(1, 82) = 1.04, *p* = .31, *ηp2* = .01. There was also no interaction for the 1st attempt, *F*(1, 82) = 1.59, *p* = .21, *ηp2* = .02; for the 2nd attempt (*F* < 1, *ns*), and for the transfer task (F < 1, *ns*).

Discussion

Hypothesis 1 predicted an animation effect and consistent with Experiment 1 no overall advantage was found for the animated format. However, support was found for Hypothesis 2 in that an interaction was found on the second attempt indicating that comparative performance between males and females was moderated by the original presentational format. Although the simple effect tests were not significant, examination of Table 3 indicates that again, females achieved higher scores than males for the animation condition, and males scored higher than females for the static condition, results consistent with the pattern identified in Experiment 1.

General discussion

A significant presentation–gender interaction was found in both experiments for this object manipulative task (Lego construction). Follow up simple effects tests indicated that for the second attempt at the completion test in Experiment 1 females scored significantly higher than males in the animated format. In contrast, this female advantage was not found for static presentations. Overall, the pattern of results was very consistent. As can be seen in Tables 1 and 3, for every test females had higher scores than males in the animated condition, but for the static condition males had higher scores than females, suggesting a clear pattern. The evidence suggests that in this learning domain with these materials, gender is an important moderator. Some caution needs to be shown in generalizing results from a single study; however, the research may be significant for a number of reasons.

Firstly, the results are consistent with previous research on gender and animation that found that animation helps female learning. However, unlike previous research that has focused mainly on learning topics related to science (Falvo & Suits, 2009; Jacek, 1997; Sánchez & Willey, 2010; Yezierskil & Birk, 2006), we conducted our study with an objective manipulative task. Investigating such a task is important, because as previously argued in our theoretical introduction, animations may be more suited to tasks involving human motion as we have we evolved cognitive mechanisms to imitate such tasks (Castro-Alonso et al., 2014a). In this study, it is potentially an important finding that females responded more favorably than males, on a task that was predicted to produce an overall animation effect (Hypothesis 1) similar to that found by Castro-Alonso (2013). It is notable that in the Castro-Alonso study, consistent with much research using Education and Psychology students, there were significantly more female participants than males. If the gender effect found in this study can be generalized then it is possible that previous studies that included high percentages of females may have been biased. Such a conclusion needs further investigation.

Secondly, the testing in Experiment 1 was conducted in a physical environment, whereas Experiment 2 was conducted on a virtual platform. The results from both experiments were fairly consistent suggesting that the type of environment did not impact on the presentation format or gender. These results are in line with other studies that have found no difference between virtual and physical environments (e.g., de Jong, Linn, & Zacharia, 2013; Klahr, Triona, & Williams, 2007; Zacharia & Olympiou, 2011), and no advantage was found for the physical environment due to the *congruence principle for effective graphics* (Tversky et al., 2002) or the *identical elements theory* (cf. Thorndike & Woodworth, 1901). Crucially gender effects did not seem to be moderated by testing format either, although it should be noted that environments were not compared directly in the same experiment.

Thirdly, together with the research indicating that males have higher spatial ability than females (e.g., Campbell & Collaer, 2009; Collins & Kimura, 1997; Feng, Spence, & Pratt, 2007; Law, Pellegrino, & Hunt, 1993; Masters, 1998; Voyer & Hou, 2006), researchers have argued that animation helps low-spatial ability learners, in particular females. However, our study measured spatial ability using the Card Rotational Test (CRT) and no gender difference was found on this test, suggesting that spatial ability could not explain the interactions found. This conclusion raises two issues. Is the Card Rotational Test a good test in relation to an animation-presentation format or motor task learning? Although used extensively as a measure of spatial ability it was designed specifically to measure mental rotation, which may not be the best index for mental animation, although the transfer test in our study required mental rotation. Further research using more extensive spatial ability tests for animation studies may be needed in future to fully explore this domain. On the other hand, if the CRT was a reliable test, then it is an open question as to what other factors may have caused the gender effects found in this study. Some researchers have argued that females might have better visual recognition memory than males (e.g., McGivern et al., 1998), which may give them an advantage in animated designs. However, it might be expected that static pictures would also benefit from enhanced visual recognition memory. Clearly more research is needed to understand why females might be advantaged by animations.

From the perspective of managing cognitive load (the theme for this special issue), the use of instructional animations is not necessarily a panacea for more effective learning. As described in the literature review, animations can create transitory information that makes learning harder than from static presentations, unless human movement skills are involved. The effectiveness of animations is dependent upon many factors such as learning content and gender. Under many conditions cognitive load will be raised using animations; hence use of animations needs to be carefully matched with learners and content to manage cognitive load. The evidence collected in this study suggests that for females, on such tasks as investigated here, using animations may have clearer advantages in managing their cognitive load rather than statics. For males, the reverse strategy may be more effective.

In summary, the main aim of the current study was to make a theoretical and empirical contribution to this general domain by comparing males with females when learning about object manipulative tasks, using both animated and static presentations. We found that for an object manipulative task (Lego construction), instructional format interacted with gender. For instructional animation, some evidence was found that university females outperformed males. However, for a statics presentation, no gender differences were found. It can be cautiously concluded, that animations enable females to learn such tasks better, but for males an animation presentation may be redundant (see Chandler & Sweller, 1991) as they can at least learn equally well from statics presentations. The next step in the process is to replicate these results through further research using different spatial ability tests and different learning domains.

Acknowledgments

This research was partially supported by funds from CONICYT (PAI, national funding research program for returning researchers from abroad, 2014, No 82140021; and Basal Funds for Centers of Excellence, Project FB0003) to the second author.

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