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Tall towers: Schemas and illusions when perceiving and remembering a familiar building

Dillon H. Murphy  | Alan D. Castel

Department of Psychology, University of California Los Angeles, Los Angeles, California, USA

Correspondence

Dillon H. Murphy, Department of Psychology, University of California, Los Angeles, Los Angeles, CA 90095, USA.
Email: dmurphy8@ucla.edu

Summary

We investigated how schemas can bias both memory and perception of a frequently seen building leading to a horizontal-vertical illusion. Specifically, undergraduate students ($n = 172$) were asked to estimate and sketch the dimensions of a highly familiar campus building to determine if they misremember or misperceive the building's features. Despite its cubic dimensions, participants frequently overestimated the building's height to width ratio, both on sketches and estimates, as they were likely biased by the horizontal-vertical illusion and the schema that buildings are often taller than wider. This occurred regardless of whether participants sketched and estimated from memory or completed these tasks while perceiving the building. Additionally, participants were often unable to correctly identify the building's outline on a recognition test, even while looking at it. These results demonstrate that both perceptual and memory accuracy can be impacted by schematic biases and cognitive illusions.

KEYWORDS

horizontal-vertical illusion, memory, perception, schemas, spatial memory

We often identify cities by their skyline or defining buildings (e.g., Buckingham Palace, Eiffel Tower, and Empire State Building) and typically use well-known landmarks for spatial navigation (Chan et al., 2012). Generally, frequent exposure or repetition improves memory (Begg & Green, 1988; but see Nickerson & Adams, 1979) and people are often good at recognizing different objects, like these landmarks, in their environment. Specifically, people have an enormous capacity for visual long-term memory (Nickerson, 1965), demonstrating high accuracy for over 2000 different images (Brady et al., 2008), and show better visual memory for objects consistent with a perceiver's expertise (Curby et al., 2009).

Despite a plethora of research demonstrating peoples' good memory for familiar objects, we often have poor memory for the details of these objects. One potential mechanism leading to a failure to notice and remember the details of both new and familiar objects is inattention blindness (Simons, 2000; Wolfe, 1999). For example, Vendetti et al. (2013) reported that office workers were frequently unable to recall the spatial layout of buttons on an elevator that they used daily. Additionally, letters and objects we see even more frequently, such as the letter "g," the American flag, pennies, or one of

the most recognizable logos in the world, the Apple logo (Farnham, 2013), have features that are also often incorrectly remembered (Blake & Castel, 2019; Blake et al., 2015; Jones, 1990; Jones & Martin, 1992; Rubin & Kontis, 1983; Wong et al., 2018). Thus, after seeing something regularly, people might expect to remember it accurately and in great detail but we often have poor memory for the features of common objects.

One explanation for these memory failures is that they reflect expectations based on statistical regularity (i.e., schemas) that can influence how we perceive and remember the world (e.g., Pichert & Anderson, 1977). While these representations can be a useful heuristic when one cannot remember something, they can also lead to predictable memory errors (schema-based intrusions). For example, Brewer and Treyns (1981) had participants wait in a graduate student office and later questioned them about the contents of that office. Although not present, participants frequently recalled the office containing books, demonstrating schema-consistent memory for objects that were not present. Further, in a seminal study, Loftus and Palmer (1974) demonstrated that participants' memory can fall victim to the influence of suggestion by using leading questions about

videos of car accidents to distort participants' memory for details of the crash. These findings indicate that, in some cases, participants' memory accuracy can be negatively influenced by schemas and suggestions when recalling information from memory. However, it remains unclear if people's perception becomes similarly biased when they observe events or objects in front of them (as opposed to recalling from the past) such that both memory and perception may be susceptible to schematic biases and cognitive illusions.

The horizontal-vertical (H-V) illusion is a well-documented perceptual illusion that refers to the tendency for people to overestimate the length of a vertical line relative to a horizontal line of equal length (Avery & Day, 1969; Howard & Templeton, 1966). This illusion may be attributable to the shape of our visual field, a horizontal ellipse, such that the vertical line's endpoints appear closer to the boundary of the visual field than the endpoints of the horizontal line (Künnapas, 1957). Regardless of the mechanism, the horizontal-vertical illusion has been demonstrated for buildings in real environments as well as pictures and virtual-reality versions of them (e.g., Yang et al., 1999); however, the magnitude of this illusion generally depends on the size of the object. Specifically, for large objects like buildings, the effect of the horizontal-vertical illusion is much greater (~20%) than for small objects (~5%; see Chapanis & Mankin, 1967; Higashiyama, 1992; see Li & Durgin, 2017 for medium-sized objects). Moreover, when observing large objects, the horizontal-vertical illusion is independent of observer orientation but the effect is retinotopic when viewing smaller objects (Klein et al., 2016).

When testing schemas and their influence on the horizontal-vertical illusion, if people believe a structure they are viewing is large (i.e., an actual building rather than a picture of one), they typically show a larger effect of the horizontal-vertical illusion (Dixon & Proffitt, 2002; Yang et al., 1999). However, research has yet to determine the effect of the horizontal-vertical illusion when recalling structures from memory. If perceptual illusions can bias memory (see Kerst & Howard, 1978; Moyer, 1973), this would provide novel insight regarding the connection between memory and perception and also show how biases in perception can influence the reconstructive nature of memory, possibly through the reliance on schemas that are stored in long-term memory.

1 | THE CURRENT STUDY

In the current study, we examined the accuracy of memory and perception for information participants encounter in their day-to-day environment. Namely, we asked participants to judge the dimensions of a familiar building, either while remembering the building or while perceiving (standing in front of) that building. Previous studies have investigated the accuracy of spatial memory (e.g., Mou & McNamara, 2002; Mou et al., 2004; Shelton & McNamara, 1997); however, this work has not evaluated the accuracy of memory for the specific features of objects in our environment (but see Stigliani et al., 2013). Additionally, previous work has demonstrated a horizontal-vertical illusion for buildings in real environments

(e.g., Dixon & Proffitt, 2002; Yang et al., 1999) but not when recalling structures from memory. We hoped to demonstrate the horizontal-vertical illusion in a real-world environment (e.g., Kingstone et al., 2003) and that this illusion results in similar, systematic errors in both memory and perception.

To examine this issue, participants were asked to estimate the dimensions and also sketch the psychology building on campus. When the building is within their sight, participants' sketches and estimates should be as accurate as or more accurate than when drawing from memory. However, despite its cubic design, we expected participants to be inaccurate in both their memory and perception of the building due to the horizontal-vertical illusion and their schematic expectations. Specifically, we anticipated that participants' mental representation of a typical tall building, as well as their schematic spatial expectations (perhaps based on statistical regularity), may bias them to remember and perceive the building as being taller and thinner than its actual cubic dimensions. Additionally, we examined whether such an illusion would be enhanced by conceptual associations such that when described as a "tower" rather than a "building," participants may be more inclined to perceive and remember the structure as being taller than wider.

Finally, previous work has demonstrated differences in participants' perceptual accuracy depending on whether cognitive illusions were measured via perception (ventral) or action (dorsal) systems. For example, people tend to be more accurate in perceptual judgments using actions (e.g., adjusting a tilt-board to match the slope of a hill; walking an estimated distance while wearing a blindfold) than giving verbal estimates (e.g., Creem & Proffitt, 1998; Loomis et al., 1992). Thus, since visual and numeric estimations can be vulnerable to cognitive illusions but motor actions (i.e., sketches) tend to be more accurate (but see Shaffer et al., 2014), we expected participants' estimates to be more biased than their sketches, but for both to fall victim to the horizontal-vertical illusion and the influence of schemas.

2 | EXPERIMENT 1

Participants either completed the task in the laboratory or worked outside with the building immediately in front of them. After receiving a sheet of paper containing a square box with which to draw the building, participants also provided estimates of its dimensions and completed a questionnaire regarding their familiarity with the building. In each condition (completing the task inside versus outside), we expected participants to overestimate the height to width ratio regardless of whether referred to as a "building" or a "tower" or whether recalling from memory or responding based on their perception.

2.1 | Method

2.1.1 | Participants

Participants (age: $M = 20.58$, $SD = 3.18$, 67 female) were 88 undergraduate students recruited from the University of California Los

Angeles Human Subjects Pool and received course credit for their participation. The sample size was selected based on prior exploratory research and the expectation of detecting a medium effect size. Participants were tested individually or in-groups of up to three individuals in a laboratory session lasting approximately 1 h. The study was completed in accordance with UCLA's Institutional Review Board.

2.1.2 | Materials

Participants were given a sheet of paper containing an empty box (6.6 inches tall by 6.6 inches wide) with which to draw the building (the psychology building at UCLA: Pritzker Hall). All participants were instructed to draw the entire building and to be as accurate as possible, including the number of windows and the general shape of the building. However, some participants ($n = 45$) were told to imagine they were standing in front of the building (recalling from memory) while others ($n = 43$) actually stood in front of it (responding based on perception). In each group, some participants' instructions used the term "psychology building" ($n = 45$) while others used the term "psychology tower" ($n = 43$).¹ Participants were also asked to make estimates of the dimensions of the building, the number of floors, the number of windows as seen from the front face of the building, and to indicate whether the building was taller than it is wider, wider than it is taller, or about the same height and width (actual dimensions: 100 feet tall, 100 feet wide, and 100 feet long). Accuracy was scored by measuring the ratio of the dimensions of participants' sketches and estimates (referred to as their bias score) in comparison to the correct ratio of 1. Whether participants first completed the sketch followed by the estimations or vice versa was counterbalanced.

2.1.3 | Procedure

Participants were randomly assigned to either complete the task inside the building in a standard testing room (containing no windows) or were escorted outside of the building to complete the task (see Figure 1). Participants were given as much time as needed to complete the task.

2.2 | Results

Example sketches from Experiment 1 are shown in Figure 2. A total of 14 participants' sketches were excluded from analysis for failing to provide an analyzable drawing that resembled the building in question (i.e., drawing asymmetrical shapes or a sloped roof that does not exist; 4), using the provided box as an outline (4), or failing to follow task instructions (6). Additionally, two participants' estimates were excluded for failing to follow task instructions.

Overall, participants' drawings had an average height of 4.23 inches and a width of 3.97 inches. Additionally, participants estimated the building to be 189.1 feet tall and 173.4 feet wide, on average



FIGURE 1 Conditions for participants completing the task outside of the building

(medians: 100.0 feet tall, 80.0 feet wide). For each participants' sketch and size estimates, we calculated the ratio of height to width to determine if they displayed a "tall towers" bias (and horizontal-vertical illusion) by reporting the building as being taller than it is wider (see Figure 3). At the subject level, 62.2% of participants' sketched ratios and 74.1% of participants' estimated ratios were greater than the correct ratio of 1. A one-sample t -test indicated that the height to width ratios of participants' sketches ($M = 1.15$, $SD = 0.38$) and estimates ($M = 1.37$, $SD = 0.56$) were significantly different than 1 across conditions [sketches: $t(73) = 3.41$, $p = .001$, $d = 0.40$; estimates: $t(85) = 6.11$, $p < .001$, $d = 0.66$]. Thus, participants' depictions of the building were generally inaccurate such that they overestimated the height to width ratio.

When inside of the building, 69.4% of participants' sketched ratios and 75.0% of participants' estimated ratios were greater than 1. Similarly, when viewing the building, 55.3% of participants' sketched ratios and 73.3% of participants' estimated ratios were greater than 1. To examine memory and perceptual accuracy, a one-sample t -test indicated that the ratios of participants' sketches from memory ($M = 1.26$, $SD = 0.46$) were significantly different than 1 [$t(35) = 3.34$, $p = .002$, $d = 0.56$]. Additionally, participants' estimated ratios from memory ($M = 1.49$, $SD = 0.63$) and based on perception ($M = 1.24$, $SD = 0.45$) were also significantly different than 1

FIGURE 2 Examples of inaccurate drawings (left) and accurate drawings (right) by participants in Experiment 1

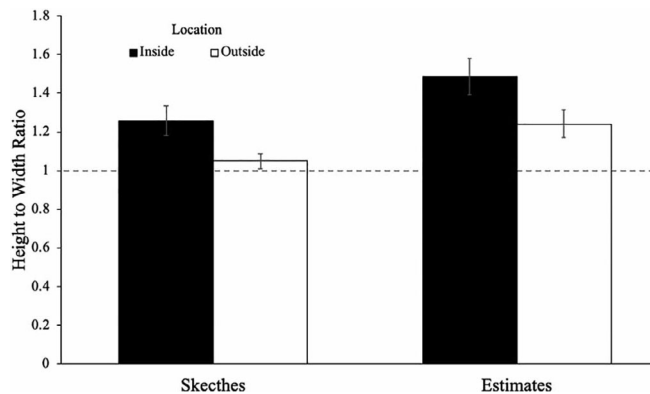
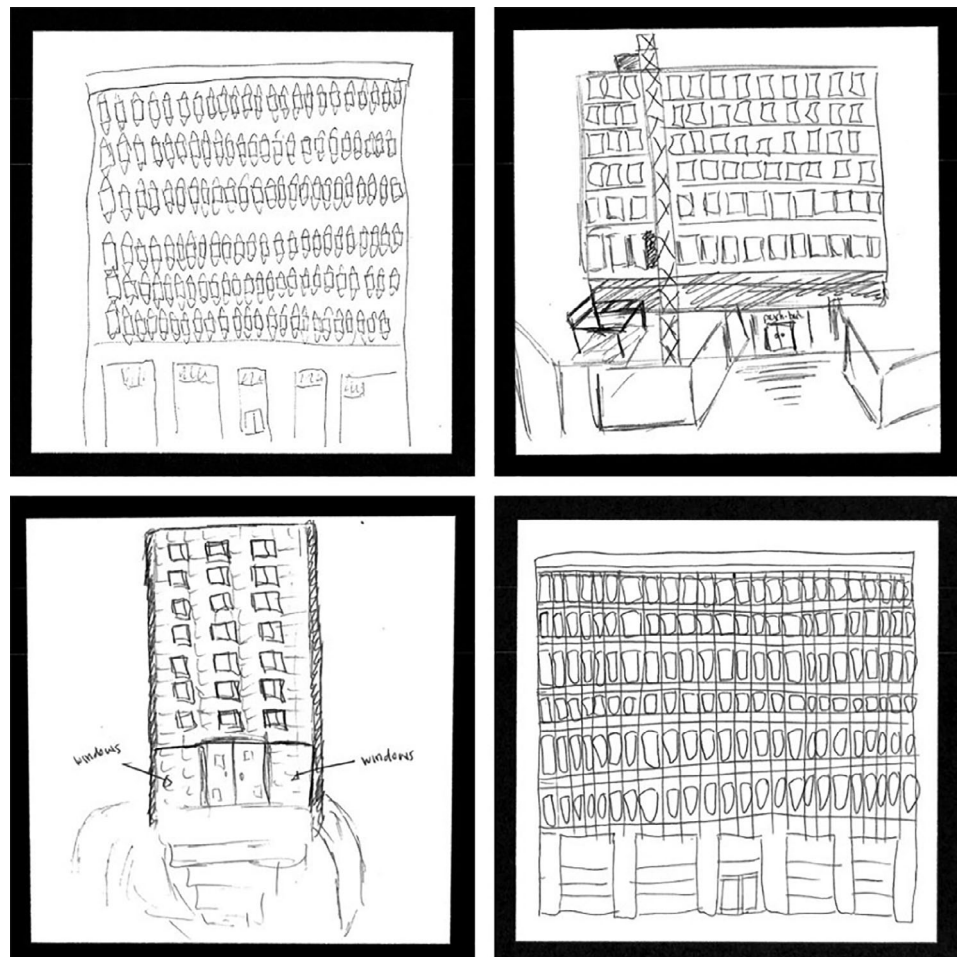


FIGURE 3 Height to width ratios as a function of response type and test location in Experiment 1. The dashed line represents the correct ratio of 1. Error bars reflect the standard error of the mean

[memory: $t(43) = 5.16, p < .001, d = 0.78$; perception: $t(41) = 3.50, p = .001, d = 0.54$] but the sketched ratios based on perception ($M = 1.05, SD = 0.25$) were not significantly different than 1, [$t(37) = 1.24, p = .224, d = 0.20$]. Thus, participants significantly overestimated the height to width ratio of the building when sketching and making estimates from memory as well as when making estimates while perceiving the building. However, participants' sketches while

looking at the building were generally accurate, suggesting that perception was not adversely affected by schemas or the horizontal-vertical illusion while looking at the building.

To further investigate possible differences in accuracy, a 2 (response type: drawings, estimates) \times 2 (location: inside, outside) \times 2 (name: building, tower) repeated-measures ANOVA on height to width ratios revealed a main effect of response type [$F(1, 70) = 14.14, p < .001, \eta^2 = 0.17$] such that participants' estimated ratios were more biased than the ratios of their drawings [$p_{\text{bonf}} < .001, d = 0.44$]. However, response type did not interact with location [$F(1, 70) = 0.04, p = .837, \eta^2 < 0.01$] or name [$F(1, 70) = 0.35, p = .558, \eta^2 < 0.01$]. Additionally, there was not a three-way interaction between response type, location, and name [$F(1, 70) = 0.14, p = .713, \eta^2 < 0.01$]. Moreover, results revealed a main effect of location [$F(1, 70) = 10.75, p = .002, \eta^2 = 0.13$] such that participants inside were more biased than participants outside [$p_{\text{bonf}} = .002, d = 0.38$]. However, results did not reveal a main effect of name [$F(1, 70) = 1.49, p = .227, \eta^2 = 0.02$] or an interaction between location and name [$F(1, 70) = 1.55, p = .218, \eta^2 = 0.02$].

Finally, when asked to indicate whether the building was taller than it is wider, wider than it is taller, or about the same height and width, 71.1% of participants answering while inside selected taller than wider, 15.6% indicated wider than taller, and 13.3% said the

height and width were the same. A Chi-square goodness of fit test indicated that the frequency of answer choices differed [$\chi^2(2) = 28.93, p < .001$]. Follow-up Chi-square goodness of fit tests between each answer choice with a Bonferroni correction revealed significant differences between the “taller than wider” and “wider than taller” selections [$\chi^2(1) = 16.03, p < .001$] as well as between the “taller than wider” and the “same height and width” selections [$\chi^2(1) = 17.79, p < .001$] but not between the “wider than taller” and the “same height and width” selections [$\chi^2(1) = 0.08, p > .999$].

When outside, 55.8% of participants selected taller than wider, 20.9% indicated wider than taller, and 23.3% said the height and width were the same. A Chi-square goodness of fit test indicated that the frequency of answer choices differed [$\chi^2(2) = 9.81, p = .007$]. Follow-up Chi-square goodness of fit tests between each answer choice with a Bonferroni correction revealed significant differences between the “taller than wider” and “wider than taller” selections [$\chi^2(1) = 6.82, p = .027$] as well as between the “taller than wider” and the “same height and width” selections [$\chi^2(1) = 5.77, p = .048$] but not between the “wider than taller” and the “same height and width” selections [$\chi^2(1) = 0.05, p > .999$]. These results revealed that holistically, the majority of participants believed that the building is taller than it is wider, regardless of whether they were recalling from memory or responding based on perception.

2.3 | Discussion

Despite having just entered the building or presently looking at it, participants' depictions were biased such that they overestimated the height to width ratio. This did not change whether referred to as a “building” or a “tower” or whether recalling from memory or when estimating based on perception. Thus, both memory and perception were generally inaccurate, possibly due to the influence of schematic expectations and the horizontal-vertical illusion.

3 | EXPERIMENT 2

In Experiment 2, rather than giving participants a square box with which to draw the building, participants were given a sheet of paper in either portrait or landscape orientation to reduce the influence of the square box on participants' sketches. We expected that the orientation of the paper might influence the accuracy of participants' sketches such that a standard 8.5 by 11-inch sheet of paper in portrait orientation might lead participants to draw the building taller and thinner than its actual size to conform to the dimensions of the paper. Additionally, similar to Experiment 1, we expected participants' sketched and estimated ratios to be significantly different from the correct ratio of 1, regardless of the orientation of the paper, whether referred to as a “building” or a “tower,” or whether recalling from memory or responding based on perception. Participants also completed a recognition test of the outline of the building to determine if they not only produce biased sketches and

estimates but also fail to recognize the correct shape, even when looking at the building.

3.1 | Method

3.1.1 | Participants

Participants (age: $M = 20.59, SD = 2.18$, 54 female) were 84 undergraduate students (40 inside, 44 outside; 40 were told to draw the “psychology building,” 44 were told to draw the “psychology tower”; 44 sketched in portrait orientation, 40 sketched in landscape orientation) recruited from the UCLA Human Subjects Pool and received course credit for their participation. A sensitivity analysis indicated that for a one-sample *t*-test, assuming $\alpha = 0.05$, power = 0.80, for a two-tailed test, the smallest effect size the design could reliably detect is $d = 0.31$.

3.1.2 | Materials and procedure

The materials and procedure in Experiment 2 were similar to Experiment 1 except that participants did not have a square box with which to draw the building. Instead, they drew on a standard 8.5 by 11-inch sheet of paper (containing only a short, two-sentence set of instructions) in either landscape or portrait orientation. As shown in Figure 4, the recognition test consisted of four outlines for participants to choose from (height to width ratios of .9, 1, 1.1, and 1.2). Participants were asked to select the option that best represents the correct height and width of the building and indicated their level of confidence in their selection from 1 to 10 (with 1 being not very confident and 10 being extremely confident). Participants also provided a reason why they made their selection. The order of the answer choices was randomized. Participants completed the task in a fixed order such that they always began with the sketch, followed by the estimates, and lastly completed the recognition test.

3.2 | Results

Example sketches from Experiment 2 are shown in Figure 5. A total of eight participants' sketches were excluded from analysis for failing to provide an analyzable drawing that resembled the building in question/that we were able to derive proper measurements from. Additionally, six participants forgot to complete the estimations and the recognition test. Overall, participants' drawings had an average height of 4.94 inches and a width of 4.55 inches and participants' estimated the building to be 183.2 feet tall and 152.4 feet wide, on average (medians: 120.0 feet tall, 100.0 feet wide). At the subject level, 64.9% of participants' sketched ratios and 84.1% of participants' estimated ratios were greater than the correct ratio of 1. To investigate possible differences in ratio accuracy across conditions (see Figure 6), a one-

FIGURE 4 Example of the recognition test in Experiment 2 with results circled. Option 2 resembles the correct height to width ratio of the building

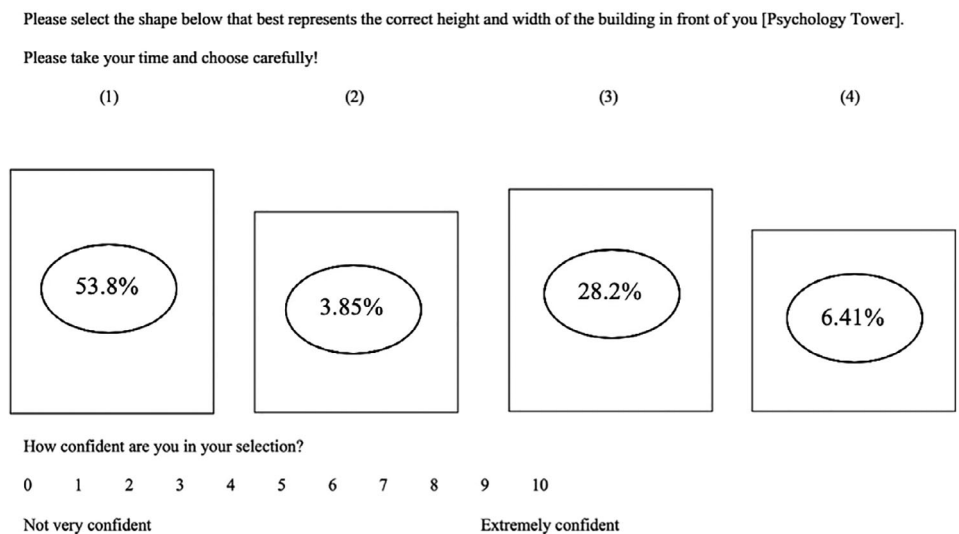
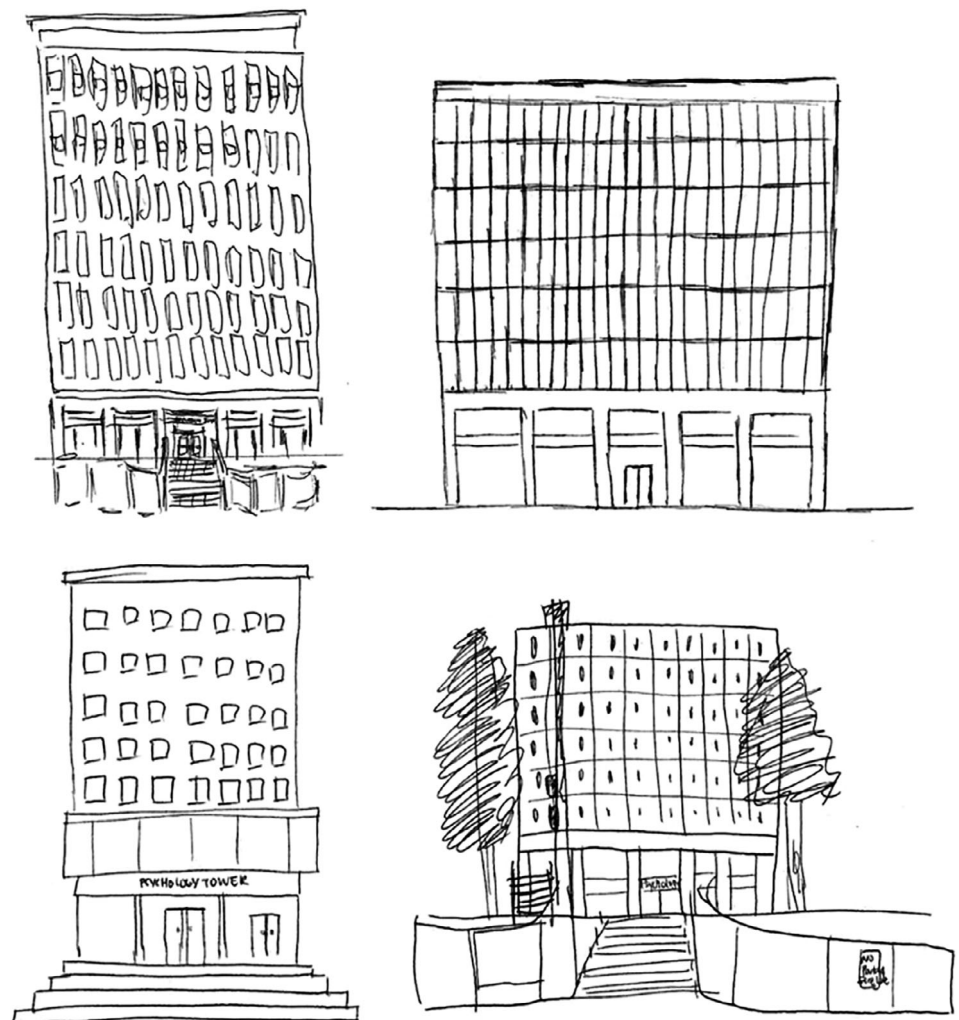


FIGURE 5 Examples of inaccurate drawings (left) and accurate drawings (right) by participants in Experiment 2



sample *t*-test indicated that the height to width ratios of participants' sketches ($M = 1.16$, $SD = 0.32$) and estimates ($M = 1.36$, $SD = 0.55$) were significantly different than 1 [sketches: $t(75) = 4.32$, $p < .001$, $d = 0.50$; estimates: $t(77) = 5.79$, $p < .001$, $d = 0.66$]. Thus, similar to

Experiment 1, participants' depictions of the building were generally inaccurate.

When inside of the building, 66.7% of participants' sketched ratios and 74.1% of participants' estimated ratios were greater than

1. Similarly, when viewing the building, 63.6% of participants' sketched ratios and 91.7% of participants' estimated ratios were greater than 1. To examine memory and perceptual accuracy, a one-sample *t*-test indicated that the ratios of participants' sketches from memory ($M = 1.23$, $SD = 0.38$) and based on perception ($M = 1.11$, $SD = 0.27$) were significantly different than 1 [memory: $t(31) = 3.46$, $p = .002$, $d = 0.61$; perception: $t(43) = 2.67$, $p = .011$, $d = 0.40$]. Similarly, participants' estimated ratios from memory ($M = 1.48$, $SD = 0.76$) and based on perception ($M = 1.27$, $SD = 0.28$) were significantly different than 1 [memory: $t(33) = 3.62$, $p < .001$, $d = 0.63$; perception: $t(43) = 6.35$, $p < .001$, $d = 0.96$]. Thus, participants significantly overestimated the height to width ratio of the building when sketching and making estimates from memory as well as when

sketching and estimating based on perception, indicating that memory and perception were similarly influenced by the horizontal-vertical illusion.

To further investigate possible differences in accuracy, a 2 (response type: drawings, estimates) \times 2 (location: inside, outside) \times 2 (name: building, tower) \times 2 (paper orientation: portrait, landscape) repeated-measures ANOVA on height to width ratios revealed is shown in Table 1. Post-hoc tests revealed that participants' estimated ratios were more biased than the ratios of the drawings [$p_{\text{bonf}} = .003$, $d = 0.37$], participants inside were more biased than participants outside [$p_{\text{bonf}} = .001$, $d = 0.44$], and participants were more biased when the instructions used the term "tower" than when using the term "building" [$p_{\text{bonf}} = .032$, $d = 0.26$] indicating that memory and perception were similarly influenced by the schema of a tall tower (but this may have been caused by a response bias; future work could examine a similar name-based manipulation using both buildings and other objects).

When asked to indicate whether the building was taller than it is wider, wider than it is taller, or about the same height and width, 76.5% of participants answering while inside indicated that the building is taller than it is wider, 20.6% selected wider than taller, and 2.9% said the height and width were the same. A Chi-square goodness of fit test indicated that the frequency of answer choices differed [$\chi^2(2) = 30.06$, $p < .001$]. Follow-up Chi-square goodness of fit tests between each answer choice revealed significant differences between the "taller than wider" and "wider than taller" selections [$\chi^2(1) = 10.94$, $p < .001$] as well as between the "taller than wider" and the "same height and width" selections [$\chi^2(1) = 23.15$, $p < .001$] and between the "wider than taller" and the "same height and width" selections [$\chi^2(1) = 4.50$, $p = .034$].

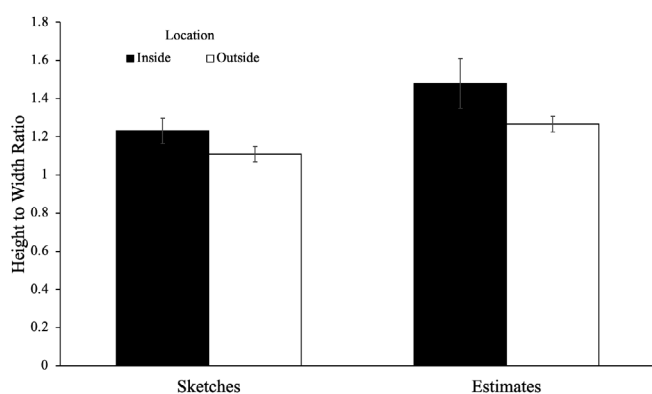


FIGURE 6 Height to width ratios as a function of response type and test location in Experiment 2. The dashed line represents the correct ratio of 1. Error bars reflect the standard error of the mean

Within subjects effects	<i>df</i>	<i>F</i>	<i>p</i>	η^2
Response Type	1	13.93	<.001	0.15
Response Type * Location	1	2.31	.133	0.03
Response Type * Orientation	1	2.12	.151	0.02
Response Type * Name	1	5.43	.023	0.06
Response Type * Location * Orientation	1	1.14	.290	0.01
Response Type * Location * Name	1	4.54	.037	0.05
Response Type * Orientation * Name	1	0.16	.691	0.00
Response Type * Location * Orientation * Name	1	0.48	.492	0.01
Residual	64			
Between subjects effects	<i>df</i>	<i>F</i>	<i>p</i>	η^2
Location	1	13.84	<.001	0.13
Orientation	1	2.08	.154	0.02
Name	1	4.80	.032	0.05
Location * Orientation	1	4.45	.039	0.04
Location * Name	1	3.05	.085	0.03
Orientation * Name	1	4.03	.049	0.04
Location * Orientation * Name	1	7.81	.007	0.08
Residual	64			

TABLE 1 A 2 (response type: drawings, estimates) \times 2 (location: inside, outside) \times 2 (name: building, tower) \times 2 (paper orientation: portrait, landscape) repeated-measures ANOVA on height to width ratios in Experiment 2

When outside, 70.5% of participants selected taller than wider, 4.5% indicated wider than taller, and 25.0% said the height and width were the same. A Chi-square goodness of fit test indicated that the frequency of answer choices differed [$\chi^2(2) = 30.05, p < .001$]. Follow-up Chi-square goodness of fit tests between each answer choice revealed significant differences between the “taller than wider” and “wider than taller” selections [$\chi^2(1) = 25.49, p < .001$] as well as between the “taller than wider” and the “same height and width” selections [$\chi^2(1) = 9.52, p = .002$] and between the “wider than taller” and the “same height and width” selections [$\chi^2(1) = 6.23, p = .013$]. Similar to Experiment 1, these results indicate that the majority of participants remembering and perceiving the building believed it was taller than it is wider.

On the recognition test, a Chi-square goodness of fit test indicated that the frequency of answer choices differed [$\chi^2(3) = 54.41, p < .001$]. Only 3 out of 78 participants (3.85%; 2 inside, 1 outside) selected the shape with the correct height to width ratio and these participants had an average confidence rating of 3.80 out of 10. The vast majority of participants selected incorrect options that fit the schema of a tall and narrow building. Of the lures, 6.41% (5.13% inside, 1.28% outside) selected the option with a ratio of .9 and had an average confidence rating of 3.33, 35.9% (7.7% inside, 28.2% outside) selected the option with a ratio of 1.1 and had an average confidence rating of 5.89, and 53.8% (28.2% inside, 25.6% outside) selected the option with a ratio of 1.2 and had an average confidence rating of 6.57. Follow-up Chi-square goodness of fit tests between each answer choice revealed significant differences between the taller than wider selections and the correct option [both $ps < .001$]. Thus, most participants failed to recognize the correct shape of the building, regardless of whether recalling from memory or based on perception.

3.3 | Discussion

Participants generally sketched and estimated the building to be taller than wider regardless of using the term “building” or “tower,” the orientation of the paper, or whether they were inside or outside the building. Additionally, participants recalling from memory (inside), as well as those whose instructions used the term “tower,” were more biased (greater overestimation of the height to width ratio). Although the methodological differences between Experiments 1 and 2 were small, the presence of the box with which participants were asked to make their sketches in Experiment 1 likely provided a cue for the correct dimensions of the building. Conversely, the standard sheets of paper used in Experiment 2 (with no box) did not provide cues regarding the correct shape of the building. Thus, without the square box to guide them, the absence of this potentially biasing information in Experiment 2 may have driven the larger effect of the “tower” title indicating that the more naive people are, the more they may be influenced by schematic expectations and potential cues. Finally, on the recognition test (somewhat akin to an eyewitness line-up test), most participants failed to identify the correct shape of the building and instead selected incorrect options that fit the schema of a tall and

narrow building, even when looking at the building. Collectively, the present results suggest that both memory and perception can be influenced by schemas and the horizontal-vertical illusion.

4 | ADDITIONAL FINDINGS

The data from the present experiments demonstrate that the horizontal-vertical illusion occurs in the perception of buildings and persists in peoples' memory for that building. The effect of schematic expectations on memory should be consistent over time but if schemas do not play an important role in the horizontal-vertical illusion, memory accuracy should be better if participants have seen the building more recently. Conversely, rather than memory processes that are prone to forgetting, if schemas do influence memory, participants' memory accuracy should be unaffected by recency effects.

To further elucidate the contributing role of memory and schemas in the horizontal-vertical illusion, we conducted an online survey of 50 UCLA undergraduates who did not participate in Experiment 1 or 2. Almost all participants had not been on campus for a prolonged period (due to COVID-19 and summer break) allowing for an assessment of how not seeing Pritzker Hall impacted their estimates of the dimensions of the building. We asked participants to provide estimates of height and width, and then asked several follow-up questions regarding the time since they last saw the building, the vividness of their memory of the building, and their familiarity with the building.

As seen in Table 2, there was no relationship between participants' bias scores (ratios of estimates of height and width) and the amount of time since they had last looked at the building, how well/vividly they remember the building, how familiar they are with the building, or how many times they have seen the building. Thus, while the horizontal-vertical illusion may be influencing participants' responses, it appears that this bias is not impacted or exacerbated by forgetting over time, suggesting that participants are likely relying on schematic expectations (possibly based on statistical regularity) as opposed to solely relying on memory in this horizontal-vertical illusion.

5 | GENERAL DISCUSSION

Although we have excellent visual long-term memory (Brady et al., 2008; Nickerson, 1965) and repetition generally helps memory (Begg & Green, 1988), we have a surprisingly poor memory for the specific details of things we see every day, such as the Apple logo or a common penny. Similarly, memory tends to be schematic (see Alba & Hasher, 1983 for a review) and can be influenced by schemas when they trigger the recall of potentially incorrect information (e.g., Brewer & Treyns, 1981). Additionally, commonly known illusions such as the Müller-Lyer Illusion, Ponzo Illusion, Shepard's Rotated Table Illusion, the Ames Room, and the horizontal-vertical illusion have exemplified instances of the inaccuracy of perception (Wolfe et al., 2006).

TABLE 2 Descriptive statistics and Pearson correlations with participants' bias scores in our online survey

Question	Mean	SD	Correlation with bias score	p-value	BF01
How many days has it been since the last time you saw the front of the Psychology Tower?	131.10	46.57	0.231	.157	1.91
How well/vividly do you remember the Psychology Tower? (1 not vivid–10 very vivid)	3.36	2.20	−0.129	.378	3.85
How familiar are you with the Psychology Tower? (1 not familiar–10 very familiar)	3.35	1.84	−0.152	.303	3.32
Please estimate how many times you have seen the Psychology Tower.	92.56	176.50	−0.144	.352	3.50

In the present study, we explored the impact of schemas and illusions on memory and perception. Specifically, we compared the accuracy of participants' estimations of a building's dimensions when recalling from memory to those responding while looking at the building. Similar to previous studies of memory for common objects, we expected that participants would be inaccurate when recalling from memory (e.g., Blake et al., 2015; Wong et al., 2018) but that they might also be inaccurate when actively perceiving the building due to the influence of the tall and narrow schema for buildings in addition to the horizontal-vertical illusion.

Results revealed systematic inaccuracy such that participants significantly overestimated the height to width ratio of the building across experiments and conditions, indicating that both memory and perception can be influenced by schemas and the horizontal-vertical illusion. Indeed, via both methods, participants' estimates and sketches appeared to conform to a schematic expectation or illusion of a building being taller than it is wider. Therefore, participants' perceptual accuracy appears to be impacted by similar biases as when recalling from memory, suggesting that schemas and the horizontal-vertical illusion affect memory and perception alike (consistent with prior work, Stigliani et al., 2013).

Some might argue that participants' inaccuracy may be due to poor artistic skills² or little experience with building design, leaving participants reliant on inaccurate schematic expectations. However, previous work has indicated that perceptual measures are more accurate when using action systems (i.e., sketches) than verbal estimates (e.g., Creem & Proffitt, 1998; Loomis et al., 1992), consistent with the results observed in the present study. Additionally, Figure 7 shows sketches from a professional and someone very familiar with the building. Although expertise generally leads to enhanced performance (Curby et al., 2009; Ericsson et al., 2018; Vogt & Magnussen, 2007), a highly experienced and professional company and someone who knows the building well exemplified the same pattern as the participants: their sketches depict the building as being taller than it is wider (4.0 inches tall, 3.1 inches wide and 4.9 inches tall, 3.1 inches wide, respectively). This suggests that even experts may fall victim to schematic and perceptual illusions, consistent with research showing that expertise can sometimes lead to false memories and biases (e.g., Castel et al., 2007). Additionally, spatial memory is influenced by task-relevant knowledge, especially when to-be-remembered information is consistent with past experience (Arbuckle et al., 1994; Hess &

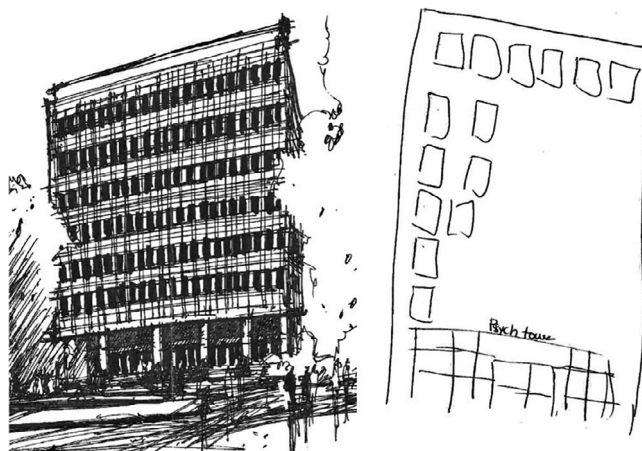


FIGURE 7 Professional sketch of the building by a graphic design company (left) and a sketch from a former student who has maintained continuous positions in the department for over 20 years and is highly involved in the current renovation of the building (right)

Slaughter, 1990). As a result, prior knowledge can influence memory to a degree that is not always beneficial when perceiving and remembering objects that are inconsistent with our schemas.

The overestimation of the height to width ratio could be due to the schema for “tall towers” but the horizontal-vertical illusion also likely plays a role. This illusion has been demonstrated for the perception of buildings (e.g., Yang et al., 1999) but the overestimation of the building's height to width ratio when recalling from memory might also stem from the horizontal-vertical illusion. Specifically, in the present study, the horizontal-vertical illusion affected participants' perception of the building but it likely also affected them in other instances when they were exposed to the building. As a result, people's perception and subsequent encoding of the building's features were likely affected by the horizontal-vertical illusion resulting in the faulty memory for the building's height to width ratio.

Additionally, schemas can drive the horizontal-vertical illusion such that when people believe that a structure they are viewing is large, they show a larger effect of the horizontal-vertical illusion (Dixon & Proffitt, 2002; Yang et al., 1999). Thus, in the present study, the selected building fits with the horizontal-vertical illusion and in combination with a tall towers bias for buildings, resulted in the

presence of this illusion both when participants perceived and remembered the building. However, although we provide some support for a schema-driven account, alternative explanations based more on perception may also be possible, including accounts that focus on mental effort (i.e., vertical is harder to perceive), danger (i.e., vertical information may contain more signals of danger), statistically-motivated distortion of angular variables (i.e., expanded vertical axis to allow for the precision of measuring space as we more often experience it), or just an anisotropy reflecting the larger horizontal distances we experience compared to experienced heights.

For our investigation, we intentionally chose a building with identical height and width allowing the selected building to fit with the horizontal-vertical illusion. However, it may be that some design features also contributed to the illusion, such as the set of vertical columns at the lower level, compared to if the building had similar features on the upper and lower portions. Future research will benefit by examining misremembering and misperception of buildings with more consistent features, different aspect ratios, as well as with other structures including iconic buildings like the Gateway Arch in St. Louis, the Eiffel Tower, or the Empire State Building. Conversely, people may notice and recognize buildings that violate standard schemas and/or have unique features, such as the shape of the Pentagon or knowing that Buckingham Palace and the White House are wider than they are taller. Additionally, future work could investigate developmental aspects of this bias/illusion to determine if children with developed/developing schematic expectations also show this effect with familiar or novel objects. While we suggest a schema-based explanation in the present study, this effect may also rely on initial perception and maintaining the representation of perception (i.e., memory), which can then be influenced by schemas, though it may be necessary to test this by using novel objects that have less schema-driven influences.

Since the horizontal-vertical illusion can influence memory in a predictable and biased manner, this effect may be broadly applicable. For example, if memory is impacted by the horizontal-vertical illusion, this illusion may also influence thinking and decision making as we often rely on information in our memory to communicate and make decisions. Thus, if perceptual information stored in memory is biased, false, or exacerbated, this can lead to people sometimes exaggerating things in terms of magnitude. However, it remains unclear whether fundamental misperception drives memory or whether the two processes are largely independent. Regardless, the present study shows that we often apply our knowledge and schematic expectations to situations that may lead to reconstructive memory errors and biases. As a result, despite frequent exposure and the apparent ease associated with recalling, recognizing, or drawing something right in front of you, memory and perception are not always as accurate as we may expect.

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CONFLICT OF INTEREST

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

ENDNOTES

- ¹ Pritzker Hall is occasionally and colloquially referred to as the Psychology Tower on campus.
- ² Additionally, both participants' drawings and their perception of their drawings may be biased by the horizontal-vertical illusion, leading to an underestimation of the size of the illusion.

DATA AVAILABILITY STATEMENT

None of the experiments reported in this article were formally preregistered. Neither the data nor the materials have been made available on a permanent third-party archive; requests for the data or materials are available from the corresponding author upon request.

ORCID

Dillon H. Murphy  <https://orcid.org/0000-0002-5604-3494>

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