Hallucinating visual structure: Individual differences in ‘scaffolded attention’

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1. Introduction

Perception often seems especially intuitive because of the apparent link between the mind and the world. When we see an object (say, an apple), that is usually because there is (at least a depiction of) a corresponding object in the world, information about which is carried by the light that reaches our eyes. As such, it seems especially striking when this link is severed — when we see objects that don’t exist in the world, and that aren’t triggered by particular cues in the incoming visual stimulation. We usually refer to such experiences as hallucinations, which we associate with contexts that seem somehow marginal or atypical — either because of the circumstances (e.g. when your eyes are closed, and you are dreaming), or the perceivers themselves (e.g. in the experiences of schizophrenic patients). But there are also curious cases of ‘everyday hallucinations’ that many people experience even while wide awake. One of the most intriguing such cases is that of scaffolded attention.

Look at the grid depicted in Fig. 1. By definition, this stimulus has no internal structure: it is built from an entirely regular arrangement of identical squares. Yet many people find that they see visual structure anyway, as in the examples depicted in Fig. 2 — a shifting array of more complex shapes (such as a ‘+’ sign), patterns (such as horizontal or vertical lines), or even block-letters (such as an H or E). In this phenomenon, the regular grid serves as a sort of ‘scaffold’ for these emerging patterns — which we do not see when just staring at a blank page. Readers (or, to foreshadow, roughly 40% of readers!) may be able to readily experience this phenomenon themselves even when just looking at the grid in Fig. 1, and of course this sort of natural, ‘everyday’ experience already makes clear that the experimental demonstration of such effects cannot be due to later confabulations based on experimenter-induced suggestibility (e.g. Lindsay, Allen, Chan, & Dahl, 2004; Young, Bentall, Slade, & Dewey, 1987).

We know of only a small number of previous studies that directly explored this sort of phenomenon, all from 25 to 45 years ago (Crassini, 1986; Farah, 1989; Heil, Rösler, & Hennighausen, 1993; Kosslyn, Cave, Provost, & von Gierke, 1988; Podgorny & Shepard, 1978, 1983). Most of these studies showed in one way or another that the squares which are highlighted as parts of the perceived higher-level patterns go on to enjoy attentional benefits, such as faster probe detection (e.g. Kosslyn et al., 1988; Podgorny & Shepard, 1978, 1983). And in addition, several

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ABSTRACT

Our perceptions usually derive their structure from particular cues in the incoming sensory information, but this is not so in the phenomenon of scaffolded attention — where shifting patterns of attention give rise to ‘everyday hallucinations’ of visual structure even in the absence of sensory cues. When looking at a piece of graph paper, for example, the squares are all identical — yet many people see a shifting array of structured patterns such as lines, crosses, or even block-letters — something that doesn’t occur when staring at a blank page. We have informally noted that scaffolded attention is a widely but not universally shared phenomenon — with some people spontaneously experiencing such perceptions (even without instruction), others seeing such ‘phantom’ structures only when actively trying to so, and still others never having such experiences at all. Accordingly, the present study assessed the prevalence of scaffolded attention — both as an ability, and a spontaneous phenomenon. These results were then correlated with several measures of imagery and attention, in an attempt to explain the nature and origin of such individual differences. 40% of observers experienced scaffolded attention spontaneously, and 78% did so when trying — and these differences were uniquely modulated by certain measures of attention (such as attentional breadth, as measured by the ‘functional field of view’), but not by measures of the vividness or spontaneity of mental imagery. These results inspire an explanation for scaffolded attention based on spontaneous perceptual grouping.
subsequent papers correlated the ability to intentionally see such patterns in the grids with individual traits or characteristics, such as age, dyslexia, and clinical symptoms such as social anxiety (Koenig, Kosslyn, & Wolff, 1991; Kosslyn & Margolis, 1990; Morrison, Amir, & Taylor, 2011; Zarrinpar, Deldin, & Kosslyn, 2006). More recently, the scope of this phenomenon has been expanded in two ways. First, recent experiments have explored not just the individual squares, but also the higher-level structured patterns that people see (as depicted in Fig. 2) — which form bona fide object representations in the visual system, that go on to enjoy phenomena such as ‘same-object advantages’ (Ongchoco & Scholl, 2019). Second, recent studies showed that this phenomenon is not specific to vision: we can also hear ‘phantom rhythms’ in regular patterns (like dripping water, or clicking metronomes), which go on to enjoy audiotemporal ‘same-event advantages’ (Ongchoco & Scholl, 2022a). And of course these differences in objective performance measures (e.g. of object-based attention) further ensure that these ‘phantom percepts’ correspond to real underlying phenomena.

1.1. The current study

All of the previous work mentioned above focused on scaffolded attention as a voluntary and intentional phenomenon, where observers were always explicitly asked to imagine a particular pattern. But scaffolded attention can also readily arise as a spontaneous experience during everyday perception, when you’re not actively trying to perceive anything — e.g. when staring at a piece of graph paper, or the tiles on an office ceiling or a bathroom floor (for a review, see Ongchoco & Scholl, 2022b). And we have also informally noted that this type of experience — while common — is not universally shared. Many people spontaneously experience scaffolded attention (even without instruction) — to the point where they find it difficult (or impossible) not to see such higher-order structures when staring at a grid. Others may not experience this as a spontaneous phenomenon (e.g. when staring at a grid with

Sample Grid

![Sample Grid](image1)

Fig. 1. A blank grid. What do you see?

Sample Patterns

![Sample Patterns](image2)

Fig. 2. Sample structured patterns that people report seeing, beyond the regular grid of squares itself.
no instructions), but may then find that they can readily see such patterns when actively trying to do so. And still others may never have such experiences at all. (And even those who do experience the phenomenon may differ in the nature of the specific patterns they perceive, and how many squares are involved in those patterns, etc.)

Inspired by these informal observations, the current experiments explored how prevalent scaffolded attention is (as both a spontaneous experience, and an ability), and what factors might explain such differences. Observers first saw a regular grid for 30 s (Fig. 3a). In Experiment 1, they were asked whether they saw any of the squares as grouped into structured shapes and patterns (as a measure of spontaneity). And in Experiment 2, they were also asked to actively try to see patterns beyond the squares themselves (as a measure of ability). In both experiments, observers also completed measures of imagery (which is perhaps the most common form of ‘seeing’ in the absence of sensory input) and of attention (given the attention-based explanations of this phenomenon). In particular, they completed the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973; Fig. 3b), the Spontaneous Use of Imagery Survey (SUIS; Reisberg, Pearson, & Kosslyn, 2003; Fig. 3c), a Functional Field of View task (FFOV, as a measure of attentional breadth; Pringle, Irwin, Kramer, & Atchley, 2001; Fig. 3d), and a Gradual Continuous Performance Task (GradCPT, as a measure of vigilance and sustained attention; Rosenberg et al., 2016; Rosenberg, Noonan, DeGutis, & Esterman, 2013; Fig. 3e). These experiments thus constitute what is, to our knowledge, the first study of individual differences in spontaneous scaffolded attention, and the results were not entirely as expected.

## 2. Experiment 1: spontaneity of scaffolded attention

To probe the prevalence of spontaneous scaffolded attention, we showed observers a regular grid for 30 s. We gave them no prompt other than to “clear your mind and pay close attention” to the grid. We were especially interested in how many people would report experiencing hallucinations via scaffolded attention — and whether such tendencies could at all be predicted by measures of attention and imagery.

### 2.1. Method

#### 2.1.1. Participants

100 observers from the Yale and New Haven communities participated in exchange for monetary payment or course credit. This sample size was determined before data collection began, was preregistered, and was fixed to be identical across the experiments reported here. Observers were 18–25 years of age ($M = 19.31$, $SD = 1.56$), and were 56% female. Observers confirmed that they had read and understood a consent form outlining the risks, benefits, compensation, and confidentiality, and that they agreed to participate in the experiment.

#### 2.1.2. Apparatus

Stimuli were presented using custom software written in Python with the PsychoPy libraries (Peirce et al., 2019) and were displayed on a monitor with a 60 Hz refresh rate. Observers sat in a dimly lit room without restraint approximately 60 cm from the display (with all visual extents reported below based on this approximate viewing distance).

### (a) Spontaneity Test
Just clear your mind and pay attention to the grid for 30 s.

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### (b) Vividness of Imagery
Rate from 1 to 5.

Think of a relative or friend whom you frequently see.

How vividly do you see the exact contours of their face, head, shoulders, and body?

How vividly do you see the characteristic poses of head, attitudes of body, etc.?

### (c) Spontaneous Use of Imagery
Rate from 1 to 5.

Indicate the degree to which this is appropriate for you.

If someone were to tell me two-digit numbers to add (e.g., 24 and 31), I would visualize them in order to add them.

When I think about a series of errands I must do, I visualize the stores I will visit.

### (d) Attentional Breadth
Find the tilted line.

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### (e) Sustained Attention
Press a key if female. Don’t press anything if male.

![Female Face]

Fig. 3. An overview of Experiment 1. (a) A test of spontaneous scaffolded attention. (b) Sample prompts from the VVIQ (a measure of vividness of imagery). (c) Sample prompts from the SUIS (a measure of spontaneous use of imagery). (c) A caricatured display from the FFOV task (a measure of attentional breadth), in which observers had to report (in a subsequent selection display) the location of a single tilted target line. (d) A caricatured display from the GradCPT task (a measure of sustained attention and vigilance), in which observers simply pressed a key every time they saw a female face, but withheld responses to (relatively rare) male faces.
The functional part of the display subtended 34.87° x 28.21°.

2.1.3. Procedure
Observers completed the experiment in five sections, always in the same order for each observer: (a) a test of spontaneous scaffolded attention, (b) a questionnaire assessing the vividness of their mental imagery, (c) a questionnaire assessing their spontaneous use of mental imagery, (d) a Functional Field of View task as a measure of attentional breadth, and (d) a Gradual-Continuous Performance task as a measure of their ability to sustain attention.

2.1.3.1. Section 1: spontaneity of scaffolded attention. In the first section, observers saw a regular 10 x 10 grid of 1.8° white squares with black borders (as in Fig. 3a). They were told to “pay close attention to the grid” and “just try as best as you can to clear your mind and simply stare at the squares” for 30 s. Afterwards, they were told that some people “find that they begin to perceive simple shapes or patterns beyond the individual squares” and were presented with examples of such patterns (similar to those in Fig. 2) — 10 x 10 grids, as in the initial display, in which squares of sample patterns (horizontal lines and a block-letter H respectively) were colored gray (#D0D3D4). Observers were then asked whether, during those initial 30 s, they found themselves spontaneously seeing any simple shapes or patterns beyond just the uniform grid of squares. If they responded ‘yes’, they were asked “For how many seconds (out of 30) did you find yourself seeing different kinds of shapes or patterns?” and “How many distinct shapes or patterns did you see?”.
They were also asked to describe in 1–2 sentences the “different sorts of shapes or patterns that you saw.”

2.1.3.2. Section 2: vividness of mental imagery. Observers next completed the Vividness of Visual Imagery Questionnaire (VVIQ: Marks, 1973). They were asked to imagine four scenes (a close friend, a rising sun, the front of a frequently visited shop, and a nature scene with trees, mountains, and a lake) one at a time, and then rate how vivid their imagery was for different aspects of the scene, on a scale of 1 to 5 (with 1 being “No image at all, you only know that you are thinking of the object” and 5 being “Perfectly clear and vivid as real seeing”). They imagined these four scenes twice: with their eyes open, and then with their eyes closed. VVIQ scores were then simply calculated as each observer’s average rating.

2.1.3.3. Section 3: spontaneity of mental imagery. Observers next completed the Spontaneous Use of Imagery Survey (SUIS; Reisberg et al., 2003), which consists of statements such as “If I am looking for new furniture in a store, I always visualize what the furniture would look like in particular places in my home.” and “If someone were to tell me two-digit numbers to add (e.g., 24 and 31), I would visualize them in order to add them.”. Observers were presented these statements (12 in total) one at a time, and were asked to indicate the degree to which the description in each statement was appropriate for them on a scale of 1 to 5, with 1 being “never appropriate”, and 5 being “always completely appropriate”. SUIS scores were then simply calculated as each observer’s average rating.

2.1.3.4. Section 4: attentional breadth (‘functional field of view’). As a measure of attentional breadth, observers next completed a Functional Field of View task (FFOV, Pringle et al., 2001). On each trial, a centered 2° fixation square was first displayed. Observers moved their mouse cursor to the fixation square, after which the cursor disappeared and 24 grey (#808080) lines (0.2° in width, and 1° in height) appeared — 23 vertical distractor lines and a single oblique target line. These lines were arrayed in eight imaginary spokes emanating from the center of the screen (four cardinal and four oblique axes, as depicted in Fig. 3d). Three lines appeared along each spoke at different eccentricities: one at 4.5°, one at 9°, and one at 13.5°. After being visible for 150 ms, each target and distractor line was masked for 1000 ms by a 1° asterisk. The display was then replaced by a response array of 24 grey circles (diameter 0.6°), one at each of the 24 locations. Observers simply clicked on the circle corresponding to the location of the oblique target line, after which the selected circle turned blue (#0000FF) for 500 ms to indicate a registered response. Observers completed 96 trials (24 possible locations x 4 repetitions), in a different random order for each observer. A composite FFOV score was then obtained by first multiplying the proportion of correct trials by factors of 10, 20, and 30 (corresponding the nearest, middle, and furthest eccentricity), and then adding these three scores (e.g. Becic, Kramer, & Boot, 2007).

2.1.3.5. Section 5: sustained attention (‘Gradual Continuous Performance Task’). In the final section, observers completed a Gradual Continuous Performance Task (GradCPT, Rosenberg et al., 2016, 2013). Stimuli were grayscale images of 10 male and 10 female faces drawn from the Chicago Face Database (Ma et al., 2015), each presented on a white background, cropped to a 7° diameter circle. The faces were presented for 800 ms each, one at a time in the center of the screen, for 10.67 min. During this time, observers viewed a total of 800 faces, 90% of which were female, and 10% of which were male (with these two categories distributed in a different random order for each observer). The specific male and female faces that were displayed given these categories were then always randomly sampled from the two sets of 10 faces, with the only constraint being that the same face could never appear twice in succession. During each 800 ms presentation, the opacities of the current image and the next image were gradually adjusted on a linear scale. (Thus, every 800 ms, a new face was presented at 100% opacity — and 400 ms after that moment of full opacity, two faces were presented each at 50% opacity.) Observers were instructed to immediately press a key whenever they saw a female face, and to not press a key whenever they saw a male face. A GradCPT score was then obtained by computing sensitivity (d').

2.2. Results
47% of observers reported experiencing spontaneous scaffolded attention; we will refer to this group as the “hallucinators”, and to the others as the “non-hallucinators”. Collectively, hallucinators perceived a wide array of patterns, including the letters “H”, ”T”, “S”, “X”, “little Ls and large Ls”, “mini crosses”, “mini boxes”, “diagonal lines”, the “shapes that different pieces [of a chessboard] would make when moved”, and “horizontal and vertical lines that sometimes intersect to form crosses or L shapes.” Our preregistered analyses involved planned comparisons between hallucinators vs. ‘non-hallucinators’, as detailed in Fig. 4a. These comparisons revealed that hallucinators had higher VVIQ scores (t (98) = 2.15, p = .034, d = .43), higher SUIS scores (t (98) = .279, p = .056, d = .56), and greater attentional breadths as measured by the FFOV (t(98) = 2.70, p = .008, d = .54) — but these groups had equivalent GradCPT scores (t(98) = .33, p = .740, d = .07). A multiple binomial regression was then used to identify which of these measures best explained the hallucinator/non-hallucinator split. Attentional breadth significantly predicted spontaneous scaffolded attention (β = 0.66, p = .007), over and above the variance explained by the other measures (VVIQ: β = .43, p = .106; SUIS: β = .51, p = .072; GradCPT: β = -.03, p = .591).
We also calculated two separate partial correlations between the four measures and (1) the duration for which hallucinators reported experiencing scaffolded attention (M = 14.02 s, SD = 6.14 s), and (2) the number of distinct patterns hallucinators saw (M = 3.62, SD = 2.06). None of the attention or imagery measures reliably predicted reported durations (VVIQ: r = -.01, p = .937; SUIS: r = -.01, p = .478; FFOV: r = -.130, p = .418; GradCPT: r = 0.10, p = .512), and only attentional breadth reliably correlated with the number of perceived patterns (r = .39, p = .009), while partialling out the variance explained by
other measures (VVIQ: \( r = 0.05, p = .733 \); SUIS: \( r = 0.18, p = .232 \); GradCPT: \( r = 0.21, p = .173 \)).

2.3. Discussion

People clearly varied in the degree to which they spontaneously experienced scaffolded attention, and this split (between hallucinators and non-hallucinators) was best predicted by attentional breadth, but not (perhaps surprisingly) by any of the imagery measures. We discuss the possible explanations for this pattern in the General Discussion, after first exploring the same correlations in the context of scaffolded attention as an ability.

3. Experiment 2: Spontaneity and Ability

Experiment 1 revealed that approximately half of observers experience spontaneous scaffolded attention, but of course this may underestimate the overall prevalence of this phenomenon, since some of the ‘non-hallucinators’ may still be able to have such experiences when actively trying to do so. In this experiment we thus replicated Experiment 1, while also exploring how the various measures of imagery and attention correlated with the ability to intentionally see such patterns.

3.1. Method

This experiment was identical to Experiment 1 except where noted. 100 new observers from the Yale community participated in an online version of the experiment for course credit, with this preregistered sample size chosen to match that of Experiment 1. Observers were 18–25 years of age (\( M = 19.05, SD = 1.06 \)), and were 80% female. After agreeing to participate, observers were redirected to a website where stimulus presentation and data collection were controlled via custom software written using a combination of HTML, CSS, JavaScript, PHP, and JsPsych libraries (De Leeuw, 2015). Observers completed the experiment on either a laptop or desktop computer.

To standardize the task across different display and monitor settings
(especially for the FFOV task), we employed a ‘virtual chinrest’ (as in Li, Joo, Yeatman, & Reinecke, 2020). This involved two tasks: a “card task”, to estimate the observer’s screen resolution, and a “blind spot task” to estimate their viewing distance. In the card task, observers were asked to place a credit card (or identification card of equal size) on the screen and to adjust a slider until the size of the image of the card on the screen matched their real-world card. In the blind spot task, observers were asked to fixate on a static black square while covering their right eye. As they did this, a red dot repeatedly moved from right to left, and they simply had to press a key when they saw the red dot disappear. These tasks yielded two values: (1) a logical pixel density and (2) a viewing distance, which we then used to compute the corresponding pixels that would match the eccentricities used in the FFOV talk from Experiment 1. Javascript code for this virtual chinrest was obtained online: https:

![Sample Percepts from Experiment 2](image-url)

**Fig. 5.** Sample percepts that observers drew in Experiment 2 (arranged in ascending number of squares involved).
After assessing the spontaneity of scaffolded attention as in Experiment 1, observers viewed the grid (500px x 500px) for another 30 s. This time, they were explicitly asked to try to see and remember the shapes or patterns beyond the individual squares. (Observers who did report spontaneously experiencing scaffolded attention were told: “This time, try to remember as best as you can the particular groups of squares, shapes, and patterns that you experience.” And those who did not report having such spontaneous experiences were told: “We’ll now show you the same grid for another 30 seconds, but this time you should actively try to notice what shapes and patterns you see.” Afterwards, they completed the same set of questions from Experiment 1, assessing how long they saw shapes and patterns for, “how many” distinct patterns they saw, and “what” distinct patterns they saw. Moreover, we now also asked observers to actively draw these patterns using an interactive grid (500px x 500px), in which they could use their mouse cursor to select (or unselect) the relevant squares. Whenever observers clicked or dragged their cursor on a white square, the square was then shaded grey (#D9D3D4); and whenever they clicked or dragged their cursor on a shaded square, the square turned back to white. Observers were told to draw one pattern at a time, and that they could submit as many as they liked. (If they saw the same pattern multiple times, they were asked to draw the pattern in the various locations in which they saw it.)

Finally, observers completed shortened versions of the task battery from Experiment 1, to minimize the total experiment time in the new online format. For the VVIQ, observers imagined only with their eyes open, and only imagined the first two of the four scenes from Experiment 1. For the FFOV, observers completed only 48 (instead of 96) experimental trials. For the GradCPT, observers completed only a 5 min (instead of 10 min) run. At the end of the experiment, we asked observers in a post-experiment debriefing questionnaire how well they paid attention (from 1 being not at all, to 10 being extremely focused). Per the prerogation, we excluded observers who responded with a subjective attention level below 80 (n = 11) and whose total completion time was more than 2 standard deviations from the mean (n = 1).

### 3.2. Results

32% of observers reported experiencing spontaneous scaffolded attention, and Fig. 5 depicts several of the patterns that they drew. Our preregistered analyses again involved planned comparisons between ‘hallucinators’ vs. ‘non-hallucinators’, as detailed in Fig. 4b. These comparisons revealed the same pattern from Experiment 1: hallucinators again had higher VVIQ scores (t(98) = 2.06, p = .042, d = 0.44), higher SUIS scores (t(98) = 2.05, p = .043, d = 0.44), and greater attentional breadths as measured by the FFOV (t(98) = 2.57, p = .012, d = 0.55) — but these groups had equivalent GradCPT scores (t(98) = 1.33, p = .188, d = 0.28). And again, only attentional breadth (β = 0.56, p = .021) significantly predicted spontaneous scaffolded attention, over and above the variance explained by the other measures (VVIQ: β = 0.33, p = .205; SUIS: β = 0.40, p = .132; GradCPT: β = 0.28, p = .224).

We again calculated two separate partial correlations between the four measures and (1) the duration for which hallucinators reported experiencing scaffolded attention (M = 16.22 s, SD = 7.41 s), and (2) the number of distinct patterns hallucinators saw (M = 5.00, SD = 1.52). As with Experiment 1, none of the attention or imagery measures reliably predicted reported durations (VVIQ: r = −0.19, p = .312; SUIS: r = 0.19, p = .313; FFOV: r = −0.07, p = .732; GradCPT: r = −0.01, p = .947), and only the spontaneous use of imagery reliably correlated with the number of perceived patterns (r = 0.53, p = .003), while partialling out the variance explained by the other measures (VVIQ: r = −0.23, p = .233; FFOV: r = 0.310, p = .102; GradCPT: r = −0.10, p = .598).

In the test of scaffolded attention as an ability (after the possibility of seeing additional patterns had already been pointed out and assessed from the first grid), 78% of observers reported being able to experience intentional scaffolded attention — and this proportion was reliably greater than that in the spontaneous test (78% vs. 32%, χ² = 40.91, p < .001). Our preregistered analyses again involved planned comparisons between those who experienced intentional scaffolded attention vs. those who did not, as detailed in Fig. 4c. These comparisons revealed that observers who experienced intentional scaffolded attention had greater attentional breadths as measured by the FFOV (t(98) = 2.46, p = .016, d = 0.59) and higher GradCPT scores (t(98) = 2.19, p = .031, d = 0.53) — but equivalent VVIQ (t(98) = 1.66, p = .099, d = 0.40) and SUIS scores (t(98) = 0.66, p = .531, d = 0.16). Both attentional breadth (β = 0.70, p = .018) and GradCPT scores (β = 0.60, p = .034) significantly predicted the ability to experience scaffolded attention, over and above the variance explained by the other measures (VVIQ: β = 0.54, p = .077; SUIS: β = −0.01, p = .974).

### 3.3. Discussion

This experiment yielded two primary results. First, scaffolded attention was more prevalent as an ability than as a spontaneous phenomenon — since the pool of people who could experience scaffolded attention (when trying to do so) was more than twice the size of the pool of people who did so spontaneously. Second, despite this difference, it was still the measures of attention (rather than imagery) that uniquely predicted whether observers could experience intentional scaffolded attention (though in this analysis, we saw such effects for both attentional breadth and sustained attention, whereas only the former played a unique role in the spontaneous experiences).

### 4. General discussion

We began this study without any clear prediction about the results. On one hand, we already knew that scaffolded attention was a real phenomenon — both from our own phenomenology, and from previous experiments (e.g. Ongchoco & Scholl, 2019). And we also knew that it was relatively widespread — both from the same previous studies, and from our experiences presenting work on this topic to various audiences. During talks, for example, it has been common for many audience members to claim excitedly that they too experienced such spontaneous percepts frequently. On the other hand, however, these same interactions with different audiences made clear that such experiences of scaffolded attention were not universal: during the same talks, some other audience members often admitted to not knowing what the others were talking about!

The current experimental studies of the prevalence of scaffolded attention clearly revealed that there are actually three groups in the underlying population. First, between a third and half of people (47% in Experiment 1, 32% in Experiment 2) are ‘spontaneous hallucinators’, who experience scaffolded attention without any instruction, when simply staring at a grid. Second, a clear majority of people (78%, in Experiment 2) are ‘intentional hallucinators’, who can experience scaffolded attention when actively trying to do so, after this possibility has already been introduced and assessed (and even if they don’t all have such experiences spontaneously). (And in our data, all of the spontaneous hallucinators were also intentional hallucinators.) Third, a sizable minority (22%, in Experiment 2) are ‘non-hallucinators’, who do not experience either spontaneous or intentional scaffolded attention.

### 4.1. Attention vs. imagery

We introduced the phenomenon of scaffolded attention by appeal to two more familiar phenomena — hallucinations, and mental imagery. But our results suggest that it cannot simply be reduced to either of these categories, and that it might instead constitute a novel form of attention.

Since people who experience scaffolded attention see structure that does not exist in the images themselves, it does seem to ‘count’ as a form of hallucination. But unlike the more familiar clinical variety of
hallucinations, we have seen that a sizeable number of observers appear to have control over whether (and perhaps what) they experience — which has led us to refer to this phenomenon as a form of “everyday hallucination”. Indeed, whereas clinical hallucinations are often considered marginal or atypical, a clear majority (78%) of observers in the present study were able to experience intentional scaffolded attention. In addition, while attention is sometimes referenced in discussions of clinical hallucinations (e.g. Collerton, Perry, & McKeith, 2005), it doesn’t play an explicit role in many prominent accounts, which refer instead to reality discrimination (e.g. Aleman, Nieuwenstein, & Bocker, 2000), or to overweighted priors (e.g. Corlett et al., 2019).

Similarly, at least three considerations suggest that scaffolded attention is not simply a phenomenon of mental imagery — despite the fact that some initial studies of such tasks (e.g. Kosslyn et al., 1988) characterized it in these terms. First, imagery is ubiquitous in a far wider variety of contexts — including when staring at an empty visual field (or when one’s eyes are closed). But the spontaneous experience of scaffolded attention, per its name, seems to require the gridlike scaffold (or a similar regular explicit pattern, in other modalities; Ongchoco & Scholl, 2022a), without which such percepts do not arise. Second, the prevalence results themselves may be difficult to reconcile with an explanation in terms of imagery. 22% of our observers failed to experience any scaffolded attention (even when prompted to encode such experiences, in Experiment 2) — whereas extremely weak or absent mental imagery (in ‘aphantasia’) has been estimated to be up to an order of magnitude less prevalent (1–4%; Dance, Ipser, & Simner, 2022; Keogh, Pearson, & Zeman, 2021; Zeman, 2020).

Third, and most importantly, we didn’t find that the vividness or spontaneity of visual imagery (as assessed with the VVIQ and SUIS measures) captured any unique variance in spontaneous (or intentional) scaffolded attention. Some such raw correlations were reliable, but that would be expected given that attention is commonly thought to play some role in mental imagery (e.g. Levine, Warach, & Farah, 1985). But when we conducted regressions to calculate which measures uniquely predicted scaffolded attention (i.e. above and beyond the others), we found that attention measures (and especially the FFOV) did so, but imagery measures did not. We conclude that scaffolded attention appears to be aptly named, insofar as it does appear to be a variety of attention. And whereas previous work has occasionally recognized this (e.g. referring to “attention-based imagery”; Kosslyn et al., 1993, p. 270), the current results suggest that the attention component may be more central than an imagery component.

4.2. From attention to grouping to everyday hallucinations

We observed two influences of attention on the prevalence of scaffolded attention. First (and less universally), the ability to sustain attention (as measured by the GradCPT task) predicted the likelihood that observers could intentionally experience scaffolded attention, but not the likelihood that they could do so spontaneously. This effect for intentional scaffolded attention may be due to the fact that there is nothing in the structureless grid itself to capture or hold attention — since (quoting James, 1890) “no one can possibly attend continuously to an object that does not change” (1890, p. 421). And this could be connected to the intentional experience of scaffolded attention, because such intentions typically involve some sustained percepts. (Our observers were presumably not trying to see only fleeting structures, as was often the case in the spontaneous experiences.) And it is not surprising that sustained attention would be implicated alone in this sense, since other work has clearly shown that it is a distinct component of attention, independent from measures of attentional breadth (Trevisio et al., 2021).

The most powerful predictor of scaffolded attention, however — in both its spontaneous and intentional varieties — was attentional breadth, which predicted the prevalence of scaffolded attention in all three central analyses (per the third column of Fig. 4), and in both in-lab studies (in Experiment 1) and with online samples (in Experiment 2). (And this link is especially notable given that the FFOV task required observers to maintain fixation, while scaffolded attention itself was assessed during free viewing.) We speculate here that this may be due to the fact that a wider attentional window allows for more squares to be grouped together into higher-level structured patterns. After all, you cannot experience multiple squares as grouped together if you’re not attending to multiple squares in the first place — and in general, past work has often found that having a relatively broad attentional scope is a prerequisite for various types of object-formation processes (e.g. Goldsmith & Yearl, 2003).

These results also raise several ideas for future work on other forms of individual differences in scaffolded attention, two of which we will mention here. First, we have anecdotally noted that scaffolded attention is still quite salient and powerful even when fixating (as many readers should be able to note for themselves when viewing Fig. 1). But that does not mean that eye movements could not be playing a role in just which particular patterns observers see from moment to moment. Future work could thus explore just how different fixation patterns (or the lack thereof) may mediate certain percepts. Second, we focused in this paper only on the brute prevalence of scaffolded attention itself, but it seems to us that the particular patterns that different observers see (per Fig. 5) could also be examined more systematically. In particular, it may be interesting to explore not only which patterns different people see, but how particular sequences of patterns may unfold (e.g. as might be predicted by adaptation to perceived patterns).

4.3. Conclusions

We already know that attention determines what we see, in the sense that without attention we may not see anything at all (as in the phenomenon of inattentional blindness; Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, 2005). In this context, the present experiments suggest that attention also determines what we see in a different way, making the difference between seeing structured objects vs. merely an unstructured scaffold.

Open practices

The pre-registered methods and analyses for both experiments can be viewed at: https://aspredicted.org/blind.php?x=qh4up7 (for Experiment 1), and https://aspredicted.org/blind.php?x=ce3jv9 (for Experiment 2).

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Competing interests statement

The authors have no competing interests.

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