

**A Parametric Framework to Generate Visual Illusions using Python**

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## Abstract

Visual illusions are fascinating phenomena that have been used and studied by artists and scientists for centuries, leading to important discoveries about the neurocognitive underpinnings of perception, consciousness, and neuropsychiatric disorders such as schizophrenia or autism. Surprisingly, despite their historical and theoretical importance as psychological stimuli, there is no dedicated software, nor consistent approach, to generate illusions in a systemic fashion. Instead, scientists have to craft them by hand in an idiosyncratic fashion, or use pre-made images not tailored for the specific needs of their studies. This, in turn, hinders the reproducibility of illusion-based research, narrowing possibilities for scientific breakthroughs and their applications. With the aim of addressing this gap, *Pyllusion* is a Python-based open-source software (freely available at <https://github.com/RealityBending/Pyllusion>), that offers a framework to manipulate and generate illusions in a systematic way, compatible with different output formats such as image files (.png, .jpg, .tiff, etc.) or experimental software (such as *PsychoPy*).

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Visual illusions have been observed for hundreds of years (Luckiesh, 1965), many of which were described in print (Helmholtz, 1856). In general terms, a visual illusion can be thought of as the inaccurate perception of a visual stimulus or a given attribute, be it geometrical (size, shape, or angle), or another property such as colour (Adelson, 2000; Delboeuf, 1893; Ebbinghaus, 1902; Howe & Purves, 2005; Muller-Lyer, 1896; Roberts et al., 2005). Often, an illusory perception resists ‘correction’ in perception even after an observer has been made aware of the misperception. Novel examples of illusions are still observed and have even cropped up on social media platforms, a famous example being ‘The Dress Illusion’ (as discussed by Schlaffke et al., 2015), which some people perceive as white and yellow, whereas others as black and blue - this is thought to illustrate how perceptual priors (i.e., expectations regarding lighting conditions) can bias our conscious representation of an object. See Ninio (2014), Luckiesh (1965), and Robinson (1972) for extensive collections of visual illusions. Overall, these illusions show how our phenomenological experience is critically shaped by contextual information and prior expectations.

Entertainment value aside, illusions have had considerable importance in the history of psychological science. Visual illusions have helped scientists understand the architecture of the eye and its relationship with processes and structures involved further up stream in the brain, the dynamic interaction of these processes, and visual coding in the brain in general (Carbon, 2014; Clifford, 2002; Forte & Clifford, 2005). Illusions such as the blind-spot or those associated with colour perception, orientation perception, and motion perception, have all been informative of neuronal activity/processes both at the level of the eye and the brain via the measurement of associated illusions (Curran et al., 2009; Durgin et al., 1995; Holland, 1965; MacKay, 1957; Webster, 1996; Witkin & Asch, 1948). Visual illusions, and perceptual illusions more generally, are a powerful tool in human perception and brain research, which in turn can inform artificial cognitive systems design considerations (Boyce

et al., 2020; Carbon, 2014). Beyond low-level perceptual mechanisms, illusions can also be powerful tools to understand higher-order processes related to phenomenal consciousness (Mahon et al., 2018), as well as neurocognitive disturbances.

In fact, illusory paradigms have been widely used to investigate these neurocognitive deficits as visual illusions highlight the influence of context on visual perception (Chen et al., 2015; Corbett & Enns, 2006; Roberts et al., 2005). Visual illusions are thus valuable tools for revealing core features of pathological conditions, such as atypical integration processes in schizophrenia (Clifford, 2014; Palmer et al., 2018; Thakkar et al., 2020). Indeed, several studies have demonstrated a diminished susceptibility to visual illusions among patients with schizophrenia relative to healthy controls (King et al., 2017; Notredame et al., 2014). Their apparent resistance to perceptual distortions, despite experiencing a wide range of cognitive deficits (e.g., working memory, object naming, concentration, Liddle, 1987), supports the idea that schizophrenia might be better characterized by a subset of specific processing abnormalities, rather than by a generalized neurocognitive impairment (Dakin et al., 2005; Tibber et al., 2013). Similarly, individuals with autistic spectrum disorder (ASD) also demonstrate an immunity to perceptual biases and are protected against the contextual influences of illusions in biasing perception, allowing them to perceive elements accurately in a local fashion (Gori et al., 2016; referred to as a ‘weak central coherence,’ Mitchell et al., 2010; Walter et al., 2009).

In summary, these studies suggest that illusions, rather than being mere perceptual artifacts, engage specific neurocognitive processes involved in important higher order functions and neuropsychiatric disorders. A common approach to explain illusory phenomena is using the Predictive Coding framework (Friston & Kiebel, 2009), which posits that illusory perception typically arises because of a strong systematic bias for prior beliefs (top-down influence) that are mismatched with actual sensory evidence, causing the generation of an objectively wrong but more plausible percept (i.e., two objectively equivalent-sized circles being interpreted as different sizes because of their surrounding context, Notredame et al., 2014). In

the case of schizophrenia and also in other states of psychosis, a greater resistance to visual illusions is then interpreted as a product of reduced adaptive top-down influence (Koethe et al., 2009; Schneider et al., 2002) and an over-reliance on sensory evidence (bottom-up processes) in making perceptual judgements (Dima et al., 2010). While evidence from visual illusions research has garnered substantial support for the predictive coding account, helping to underscore the neurocomputational mechanisms that are fundamental to psychiatric and psychological disorders (Sterzer et al., 2018), there are contradictory findings that fail to be integrated within this approach. The lack of consistency and replicability in experimental designs using illusion-based stimuli appear to be one of the main hurdles precluding theoretical consensus in the field.

This is especially true given that the perceived illusion is affected by manipulating specific stimulus features. For instance, studies have shown that inverting the orientation of the illusion (by 180 degrees) can influence perceptions of the Contrast and Ponzo illusion where in both cases, illusion magnitude is greater when the illusion presentation is in their upright positions (Poom, 2020). For the Ponzo illusion, this may be explained by the higher familiarity with ground planes like roads and railways receding in the distance (rather than towards us). The Ponzo illusion is also perceived to be stronger when wedges are of intermediate lengths (as compared to shorter and longer wedges) and of higher lightness contrast relative to the enclosed horizontal target lines (Jaeger et al., 1980). Similar patterns have been reported for the Müller-Lyer illusion, where wings (or fins) of intermediate lengths and of greatest contrast relative to the horizontal shafts increased the tendency to overestimate the shaft lengths (Jaeger, 1975; Restle & Decker, 1977; Wickelgren, 1965). However, varying stimulus features does not always produce consistent results in terms of the perceived illusion, with existing theories generating different predictions of illusion strength as a function of their parametric properties (Woloszyn, 2010). For the Ebbinghaus illusion - of which some proponents have argued is a variant of the Delboeuf illusion (e.g., Weintraub & Schneck, 1986) - it is not clear whether manipulating the distance between the surrounding and target circles in

the former interacts with the size of the surrounding context circles in affecting the illusion magnitude (Girgus et al., 1972). There are also mixed findings regarding whether adding smaller surrounding circles increases or decreases the perceived size of the target circle in the Ebbinghaus illusion (Jaeger, 1978; Massaro & Anderson, 1971). Although conflicting findings have been taken as support for respective competing theories (Jaeger & Klahs, 2015), a general understanding of the fundamental parameters underlying the various illusions is still lacking.

The effects of these parametric properties are especially important for illusions that have been used to explain real life phenomena. For instance, the Delboeuf illusion has often been referenced in studies of dieting and perceived food portions (McClain et al., 2014; e.g., Van Ittersum & Wansink, 2012). The overestimation of food portions when served on plates with wider rims (i.e., rim surrounds food more closely) and colored rims (i.e., greater color contrast between border and food) has been attributed to the effect of central parametric properties like proximity (Girgus & Coren, 1982; Jaeger & Long, 2007; Surkys et al., 2006) and color contrast (Oyama & Akatsuka, 1962; Weintraub & Cooper, 1972) underlying the Delboeuf illusion. This has important implications for eating behaviour and weight control (McClain et al., 2014). Another applied usage of illusions can be found in the study of goalkeeper postures. Perceptions of a larger-than-usual goalkeeper, reducing penalty-taking accuracy (Kamp & Masters, 2008), is facilitated when arms are raised at higher angles. This has been linked to the Müller-Lyer illusion, in which increasing angles of the wings (deflected away to a maximum of 160 degrees) causes an overestimation of the shaft lengths (Restle & Decker, 1977).

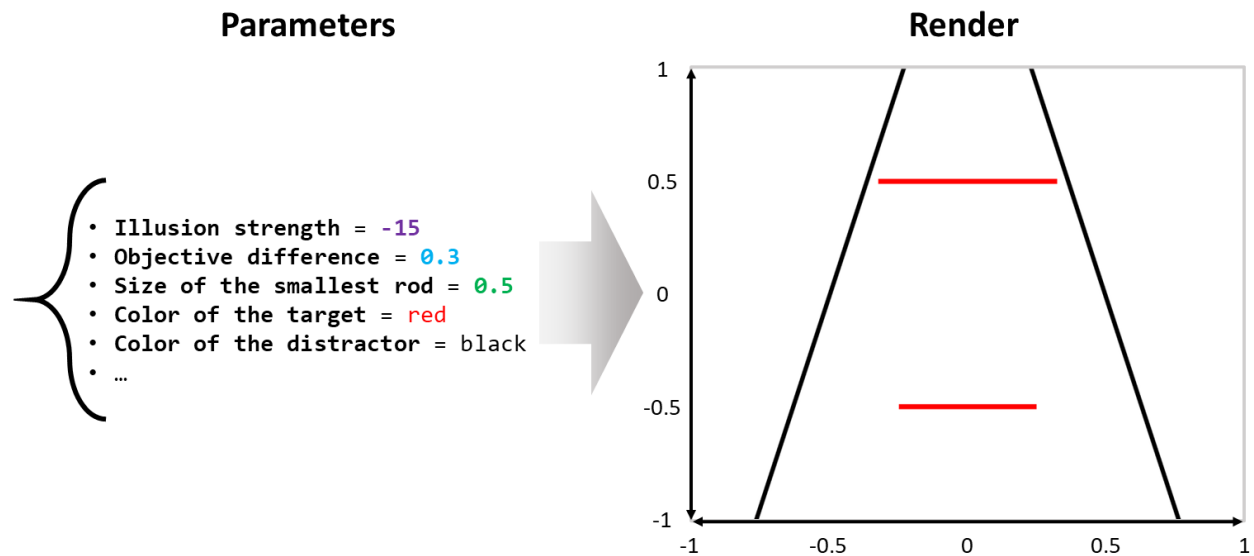
The aforementioned usage of visual illusions to study psychopathology is precisely related to their inherent parametric properties, which allow them to capture distinct neurocognitive processes. One study found that patients with schizophrenia showed a heightened resistance to contrast illusions despite being indistinguishable from healthy controls in judging brightness illusions (Tibber et al., 2013), arguing against a broad deficit in low-level perceptual

integration since not all illusions are affected. However, an increased perceptual accuracy towards high-level illusions has failed to replicate in several other studies (e.g., Parnas et al., 2001; Spencer & Ghorashi, 2014; Yang et al., 2013), and other kinds of illusions (e.g., the Poggendorff illusion) have simply not been sufficiently tested (Kantrowitz et al., 2009). Findings of illusion resistance amongst ASD face similar low replicability rates as with the literature on schizophrenia, even when the same illusion tasks are used (Hoy et al., 2004; Ropar & Mitchell, 1999). Potentially, this may be attributed not only to the heterogenous nature of ASD as a clinical population, but also to the large variability in experimental instructions (e.g., asking whether lines: “looked the same length”; vs. “were the same length,” see Happe & Frith, 2006) and the subsequent understanding of the task requirements (Chouinard et al., 2013). Overall, the lack of consistency in the tasks’ methodologies has posed a significant challenge to advancing our theoretical understanding of the role of visual perception and reality construction in psychopathology (King et al., 2017).

Despite the relevance of visual illusions in psychology and neuroscience, the field of illusion research lacks a dedicated software to generate and report the stimuli, in order for them to be reproduced and re-used by other researchers and studies. As several reviews have highlighted (e.g., Gori et al., 2016), the lack of a validated paradigm and the improper measurement of visual illusion sensitivity (especially amongst individuals with communication problems) may be preventing progress in understanding the distinct mechanisms that underlie psychopathology and other fields alike. This is particularly problematic in the context of the replicability and reproducibility issues recently outlined in psychological science (Maizey & Tzavella, 2019; Milkowski et al., 2018; Nosek et al., 2015; Topalidou et al., 2015). Thus, there is a need for the creation of experimental paradigms where results can be consistently interpreted with respect to the parametric properties of the visual illusion. Our software, *Pyllusion*, aims at addressing this gap by proposing and implementing a parametric framework for illusions generation.

## A Parametric Framework for Illusion Research

The core idea of the “parametric” approach proposed here and implemented in *Pyllusion* is to dissociate the parameters of an illusion from its rendered output. For instance, the Ponzo illusion (see **Fig. 1**) can be described in terms of properties of the “distractor” lines (which induce the illusion), such as the angle (related to the illusion strength), the color, width, etc. and properties of the “target” lines (which are affected in perception by the illusion), such as the size of the smallest line, the objective difference of the ratio of their lengths, or their color, width, etc. This set of parameters can then be rendered in different formats with further format-specific characteristics (in the case of images, the image size, ratio, resolution, compression, etc.).



**Figure 1.** The parametric framework for illusions originally implemented in *Pyllusion* aims at dissociating the parametric representation of an illusion (on the left) from its rendered representation, in this case as an image of the Ponzo illusion (on the right). In technical terms, an illusion strength of -15 represents a 15 degree tilt of the vertical lines (black distractor lines); an objective difference of 0.3 represents a 30% length difference of the upper and lower horizontal lines (red target lines) where the size of the shorter horizontal line is 0.5.



This essentially allows researchers to describe, manipulate, process and share their stimuli in a concise yet consistent way. For instance, researchers could report a “*linear modulation of the illusion strength between -15 and 15, resulting in a reduced reaction time of...*”, providing details about the remaining parameters, as well as the Python code used to fully reproduce their stimuli.

Moreover, this parametric approach is scalable and works well with different kinds of illusions, as demonstrated in the software. Indeed, many visual illusions (especially the classical ones) appear to have relatively similar parameters (such as a feature - like the angle or the size of some shapes - related to the strength of the illusion, or the color of the “target” objects), which in turn allows for a consistent application programming interface (API).

Interestingly, in most of the visual illusions, the strength of the illusion can be dissociated from the actual “difference” (which is impacted by the illusion). For instance, in the Müller-Lyer illusion (see **Fig. 1**), the difference between the two horizontal segments can be modulated orthogonally from the angle of the “distractors” arrows. Allowing researchers to easily manipulate these parameters opens the door for potentially interesting paradigms and experiments. In the following section, we will describe with concrete examples how we operationalized such a parametric approach in the *Pyllusion* software.

## Pyllusion

This is not the first time that Python, illusions and cognitive science are brought together. In his book, “*Programming visual illusions for everyone*”, Bertamini (2017) describes how to use *PsychoPy* to generate famous illusions. That said, although being a fantastic tool and resource for researchers and anybody interested in illusions, it is presented as a fun introduction to programming and to Python, rather than a dedicated software for illusions *per se*.

*Pyllusion* is an open-source package to programmatically generate illusions written in Python

3 (Van Rossum & Drake, 2009), which means that its users benefit from a large number of learning resources and a vibrant community. However, although being a programming-based tool, users not familiar with Python or other languages can easily use it as well, as it requires minimal programming skills (one can essentially copy the few necessary lines from the documentation and tweak the explicitly-named parameters). This makes it a very flexible tool; advanced users can incorporate *Pyllusion* in their scripts or experiments (for instance, to generate illusions “on the fly” based on the input of the user), whereas novice users can simply copy the minimal code to pre-generate and save the illusions as images.

The source code is available under the MIT license on GitHub (<https://github.com/RealityBending/Pyllusion>). Its documentation is automatically built and rendered from the code and includes guides for installation, a description of the package’s functions, as well as examples of use. Finally, the issue tracker on GitHub offers a convenient and public forum that allows users to report bugs, get help and gain insight into the development of the package. Additionally, the repository leverages a comprehensive test suite (using *pytest*) and continuous integration (using GitHub actions) to ensure software stability and quality. The test coverage and build status can transparently be tracked via the GitHub repository. Thanks to its collaborative and open development, *Pyllusion* can continuously evolve, adapt, and integrate new functionalities to meet the needs of the community.

*Pyllusion* is available on PyPI, the main repository of software for Python and can thus be installed by running the command `pip install pyllusion`. Once the software is installed, it must be loaded in Python scripts with `import pyllusion`. This stores the *Pyllusion* module locally and makes functions accessible by calling `pyllusion`.

Once the package is loaded, two further steps are required to generate the illusions, 1) specifying the parameters and 2) rendering the output accordingly.

We will use the Delboeuf illusion in the hands-on example shown below. However, the same workflow applies to the other illusions supported by *Pyllusion*, including the Ebbinghaus

illusion, the Müller-Lyer illusion, the Ponzo illusion, the Zöllner illusion, the Rod and Frame illusion, the Poggendorff illusion and more (see **Fig. 2**, as well as the full list with examples on the **readme**).

## Step 1: Parameters

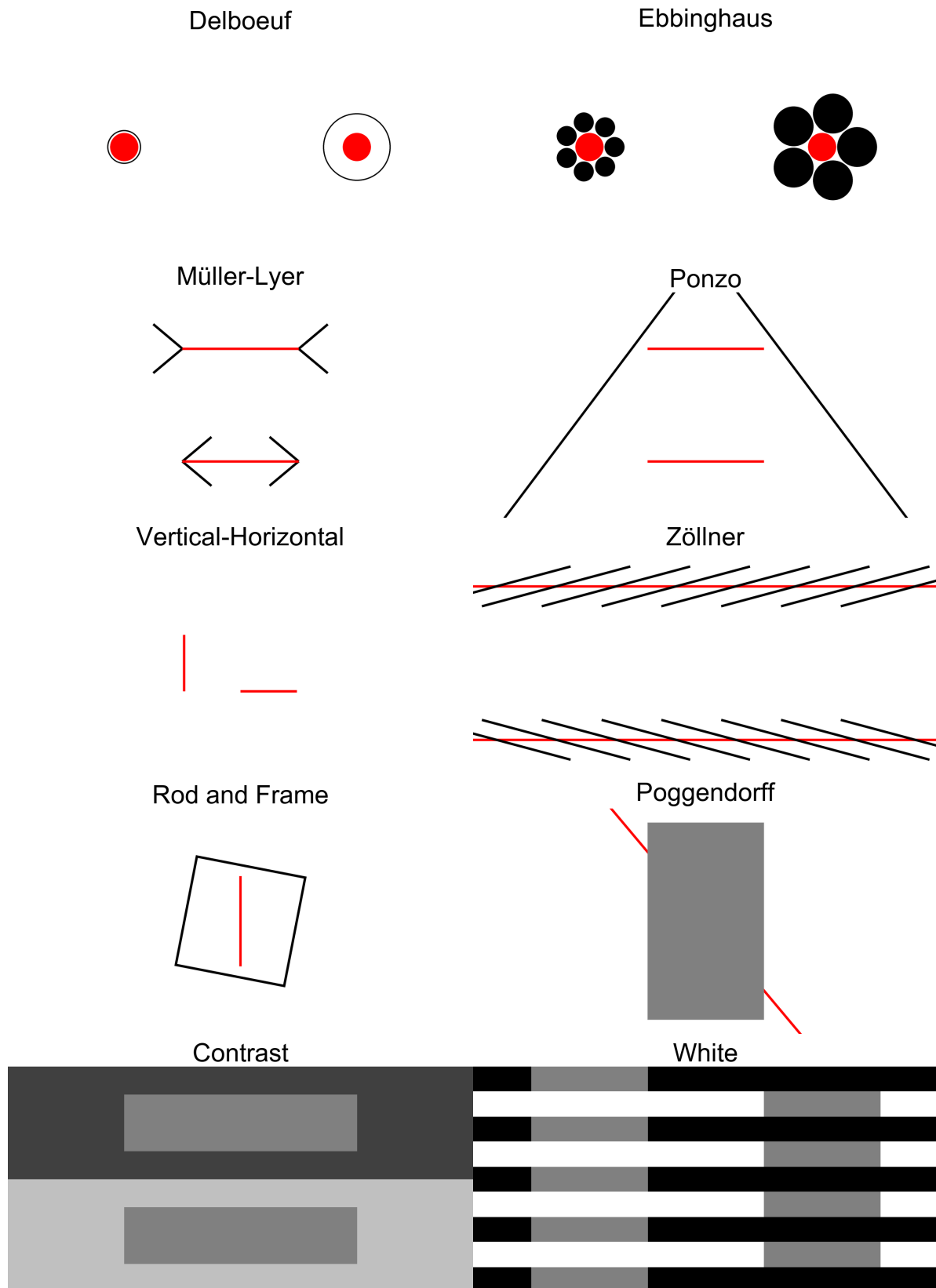
The parameters for each illusion can be generated using the `IllusionName_parameters()` function. Many optional arguments are available for modifying, of which the description and default values can be found in the API documentation (<https://realitybending.github.io/Pyllusion/functions>). In the example below, we specify the `illusion_strength` argument, and the function will compute all of the remaining parameters accordingly.

```
# Load package
import pyllusion

# Create parameters
parameters = pyllusion.delboeuf_parameters(illusion_strength=2, difference=0)

# Visualize parameters
print(parameters)
```

```
{'Difference': 0,
 'Size_Inner_Left': 0.25,
 'Size_Inner_Right': 0.25,
 'Size_Inner_Difference': 0.0,
 'Illusion': 'Delboeuf',
 'Illusion_Strength': 2,
 'Illusion_Type': 'Congruent',
 'Size_Outer_Left': 0.3,
```



**Figure 2.** Different classical visual illusions currently supported by *Pyllusion*. These can all be generated using the parametric approach described in this paper, allowing for fully reproducible studies.

```
'Size_Outer_Right': 0.52,  
'Distance_Centers': 1,  
'Distance_Edges_Inner': 0.75,  
'Distance_Edges_Outer': 0.59,  
...}
```

232 As one can see, the output of this function is a basic Python dictionary (as denoted by the  
233 curly brackets), which makes it easy to further process, modify, share, store or investigate.  
234 This “container” object stores the values for a large number of parameters, such as the size  
235 of each (inner and outer) circle, the distance between the centers and edges of the circles,  
236 and their position, which is then passed to a “rendering” function which converts this set of  
237 parameters into the final output.

238 Note the two main parameters, `illusion_strength`, and `difference`, have fairly generic  
239 names, as the meaning of these parameters fundamentally depends on the nature of the  
240 illusion. For instance, while `illusion_strength` refers to the angle of the non-horizontal  
241 lines in the Ponzo illusion (in biasing the appearance of the target horizontal lines) it refers  
242 to the area of the outer circles in the Delboeuf illusion. In the case of the latter, an illusion  
243 strength of 2 (as shown in the above script) means that the size of the right outer circle will  
244 be 2 times larger than that of the right inner circle, while the left inner and outer circles  
245 remain equally sized with each other, thus creating a false perception that the right inner  
246 circle appears larger than its left counterpart. Conceptually, this term represents the extent  
247 to which the surrounding context biases the perceptual experience (see **Fig. 2**). On the  
248 other hand, the `difference` parameter refers to the objective difference in the features of  
249 the to-be-compared targets, such as the difference in sizes of two inner circles (Delboeuf  
250 and Ebbinghaus illusion), and the lengths (Ponzo and Müller-Lyer illusion) or the angle  
251 displacement (Zöllner illusion) of two horizontal lines. In the above example, a difference of  
252 0 implies that the left inner circle and the right inner circle are of the same size. Specification

of this parameter (i.e.,  $\text{difference} \neq 0$ ) can be used to modify the actual target difference so that there exists an objectively correct answer when subjects are tested with these illusions.

Although less abstract names for these arguments (for example, `difference_size_outer_circles` and `difference_size_inner_circles` to represent illusion strength for Delboeuf illusion), the decision to unify the inducing parameters under the “illusion strength” and “difference” labels was further motivated by the aim of having a consistent naming scheme for the API. This means that users can experiment with new illusions by modulating the illusion strength and objective target features, without the need of learning what is the actual physical parameter (e.g., “angle of the distractor lines”) driving the illusion.

## Step 2: Rendering

The dictionary containing the parameters of the illusion, can then be passed to a “rendering” function, which actually draws (or displays) the illusion according to the specifications. Render-specific arguments are available at this stage, such as the dimensions of the image. Two output-engines are currently supported, images (in any format thanks to the PIL Python library for image processing, Clark, 2015), or as *PsychoPy* stimuli (Peirce, 2007), one of the most popular psychological experiments software.

**Images.** Each function is illusion-specific and hence, uniform function names (in the form `IllusionName_FunctionGoal()`) are used in the process of creating the illusion. Parameters are computed using `*_parameters()` (the asterisk representing the illusion name), and images can be generated via `*_image()` (or similarly, `*_psychopy()`, as we will see later).

The following Python code shows the full and reproducible code to generate a PNG image with a Delboeuf illusion. However, note that the parameters generation and the rendering have been dissociated for illustrative purposes. In practice, the arguments related to the parameters of the illusion can be passed directly to the rendering function, which will automatically compute the parameters if no dictionary is passed. Similarly, the saving step

278 can be done directly by adding `.save()` at the end of the the `*_image()` function, which  
279 reduces the amount of Python lines to one.

```
# Load package
import pyllusion

# Create parameters
parameters = pyllusion.delboeuf_parameters(illusion_strength=1, difference=2)

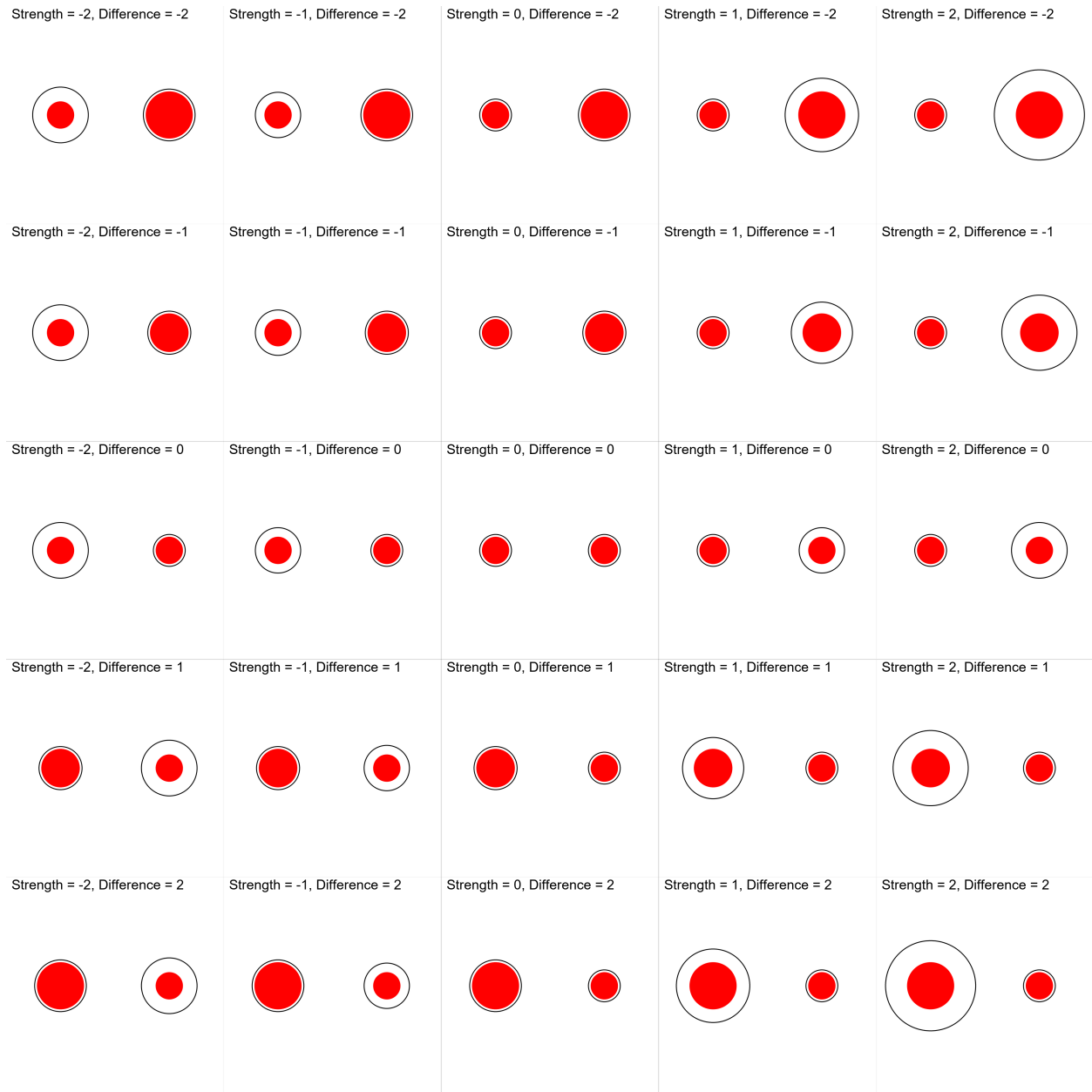
# Generate image from parameters
image = pyllusion.delboeuf_image(parameters, height=600, width=800)

# Save it
image.save("my_illusion.png")
```

280 Images can be generated in different resolutions using the `width` and `height` argument (in  
281 pixels), and can be further post-processed using the PIL library. With just a few lines, one  
282 can loop through different combinations of parameters, generate illusions, add text on them,  
283 and collate together in a mosaic, as can be seen in **Fig. 3**.

284 **PsychoPy.** As illusions are frequently used in experimental psychology, we designed *Pyl-*  
285 *lusion* so that it is directly usable within *PsychoPy* (Peirce, 2007) experiments. *PsychoPy* is  
286 an open-source, free and Python-based package for experiment creation, recognized for its  
287 timing accuracy (Bridges et al., 2020) and its GUI (the “builder”), thereby allowing users  
288 who are not familiar with code to easily build experiments.

289 The *PsychoPy* “builder” interface allows for code components to be flexibly added, which  
290 makes it convenient to insert the few lines necessary for displaying illusions. However, using  
291 the programming interface of *PsychoPy* (which underlies the graphical interface) reveals how  
292 seamless the integration with *Pyllusion* can be. The following code is a minimal example



**Figure 3.** Different combinations of illusion strength and objective difference between the two target stimuli (the area of the red circles) for the Delboeuf illusion. The vertical central column shows varying magnitudes of size difference in both directions with no illusion, whereas the horizontal central row shows different magnitudes of illusion strength when the targets are of identical sizes. By using negative or positive values for the illusion strength, one can generate congruent or incongruent illusions (that reinforce or attenuate the actual difference respectively).



293 demonstrating how to use a Delboeuf illusion within a *PsychoPy* workflow. Running it opens  
294 a new window, displays the illusion in it, and then closes it once an input (a key press) is  
295 detected.

```
# Load packages
import pyllusion
from psychopy import visual, event

# Create parameters
parameters = pyllusion.delboeuf_parameters(illusion_strength=1, difference=2)

# Initiate Window
window = visual.Window(size=[800, 600], winType='pygame', color='white')

# Display illusion
pyllusion.delboeuf_psychopy(window=window, parameters=parameters)

# Refresh and close window
window.flip()
event.waitKeys() # Press any key to close
window.close()
```

296 This native integration with *PsychoPy* could appear as somewhat redundant and unneces-  
297 sary, as one could pre-generate all the illusions as images, and simply load them in *PsychoPy*  
298 as images, instead of generating them from scratch using *PsychoPy*'s drawing functionalities.  
299 However, this direct integration in experiment building software has multiple benefits, such  
300 as avoiding the storage of large image file sizes (resulting in more efficient use of space for  
301 experiments that can be uploaded and stored online), avoiding issues of image scaling and

resolution on different screens, and allowing “on-the-fly” generation of stimuli, which opens the door for novel adaptive paradigms where the modulation of illusions crucially depends on the participant’s input.

## Future Plans and Developments

Being an open-source software, *Pyllusion* will continue to grow and evolve based on the community’s input and needs. While the direction and state of the package in the long term can be hard to predict, several short term goals are highlighted below.

The initial release of *Pyllusion* focuses on a set of classical, well-described, visual illusions, as they are the most commonly used (for historical reasons mainly, as well as for their relative simplicity). That said, the number of existing illusions, or variations therein, is virtually infinite (and great advances are made to generate new ones using machine learning, Watanabe et al., 2018). Thus, new illusions, as well as new illusion types (e.g., movement-based using GIF or video formats, or auditory illusions using sounds and music) could be added in the future. Due to the open and collaborative nature of the software, these evolutions will be driven by the needs of the community, ensuring that *Pyllusion* remains cutting-edge, adaptable and useful to address future issues.

Adding new illusions refers mostly to implementing an algorithm to conceptualise and essentialize them as sets of parameters, which is by design independent from their rendering. However, more rendering engines could be added down the road. For instance, one of the first milestones could take the form of an integration with other Python-based experiment building software, such as *OpenSesame* (Mathot et al., 2012) or *Neuropsychia* (Makowski & Dutriaux, 2017). Additionally, a conversion to other languages could also be an interesting feature, especially *JavaScript*, as this would allow a closer integration with web browser apps Henninger et al. (2020). That said, a simple alternative is to generate illusions as images using *Pyllusion* and displaying them as such on websites or any other experimental software.

Finally, additional practical considerations are warranted when using *Pyllusion*, depending on the research question and the specific visual illusion of interest. Firstly, it is important that viewing conditions are controlled for in any illusion-based experiments. Factors such as how brightly lit the experimental room is and the contrast luminance of the monitor can affect judgments of contrast, and viewing distances and sitting postures may confound perceptions of length, size, and angles. Additionally, while binocular vision is superior in most tasks (e.g., luminance and color discrimination, vernier acuity etc.), some evidence suggests that the vertical-horizontal illusion (requiring the judgment of a vertical line relative to a horizontal line) appears to be an exception, with monocular vision substantially reducing the illusion and binocular vision enhancing it (Prinzmetal & Gettleman, 1993). One reason seems to be that the monocular visual field is less asymmetric than the latter (Avery & Day, 1969), and any visual illusion that is modulated by asymmetric visual fields may need to take this into consideration. Another crucial, but relatively uncharted territory, is the investigation of how visual illusions are temporally processed. Recent research has shown that the perceived illusion is dependent on inspection time (i.e., for some illusions, a longer time is required to attentionally disregard the biasing context), and that this effect is unique to each illusion (Bressan & Kramer, 2021). The Ponzo illusion, for example, induces illusion susceptibility under presentation times as short as 12 ms (Schmidt & Haberkamp, 2016). Thus, it is critical that illusion-based experiments carefully operationalize presentation times with refresh rates appropriate for the specific illusion of interest.

Overall, we look forward to the creation of studies that would investigate how, for each illusion, the modulation of the parameters affect behavioural responses, conscious perception, and the associated neural underpinnings. This would in turn allow for a better understanding of the commonalities and differences between these fascinating stimuli, as well as their effect across different populations (such as patients suffering from neuropsychiatric disorders). As such, we hope that our tool contributes to the development of a strong axis that will unite the community working with illusions to push the field forward.

### **Conflict of Interest Statement**

354

355 The authors declare that the research was conducted in the absence of any commercial or  
356 financial relationships that could be construed as a potential conflict of interest.

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