Sensory mechanisms of perceptual uniformity

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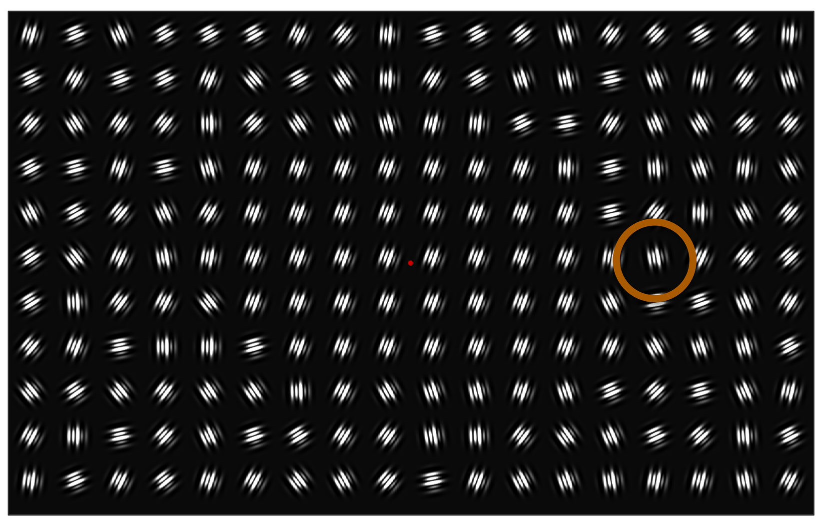
BACKGROUND: Visual experience appears rich in detail despite the poor performance of the vast majority of the visual field, as a result of the integration of coarse peripheral signals with the information of the comparatively tiny fovea. We examined the mechanisms of this integration by employing the uniformity illusion, in which a pattern with different properties in fovea and periphery uniformly takes the appearance of the fovea[1]. We employed two different perceptual dimensions (orientation and spatial density) to investigate the extent to which the uniformity illusion is associated with changes in sensory encoding.

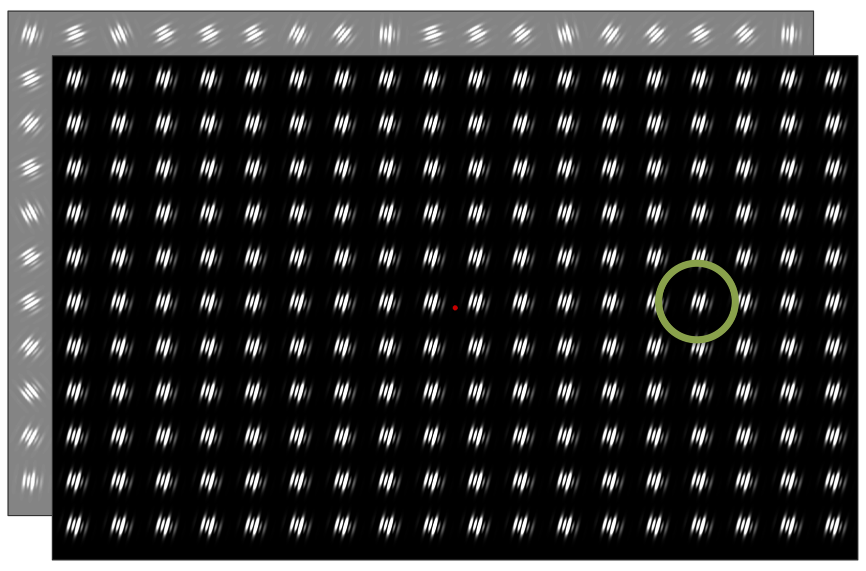
1. UNIFORMITY ILLUSION ON ORIENTATION

1.1. METHODS

ADAPTATION PHASE (180 SECONDS)



During the **adaptation phase**, participants are presented with a Gabor grid able to produce the uniformity illusion affecting the orientation of the peripheral elements. Eye-tracking ensures that each Gabor patch is received on a specific retinal location, as the pattern is removed if the participant's gaze deviates from the fixation point.



Under the uniformity illusion, all Gabors appear to take the orientation of the central area. Participants report the illusion by holding down a key, allowing us to measure the **time of perceived uniformity.**

In the **control session** (physical uniformity session), the pattern is replaced by a truly uniform Gabor grid at the exact times in which participants reported (illusory) uniformity in the previous session, allowing us to directly compare illusory and physical-driven effects.

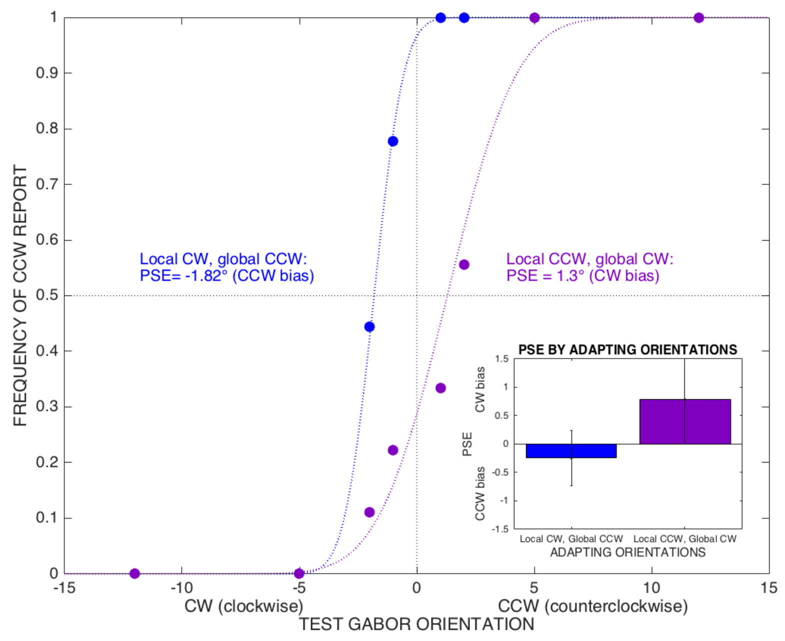
TEST PHASE (0.5 SECONDS PER STIMULUS)

During the **test phase**, a single Gabor patch is briefly presented on a specific peripheral location. Participants report whether it is tilted clockwise or counter-clockwise. We examine which of the two competing orientations causes a tilt after-effect: the **local** (physical) and **global** (illusory).

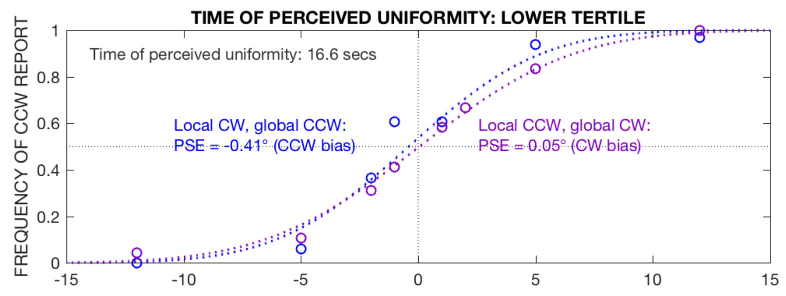
1.2. RESULTS

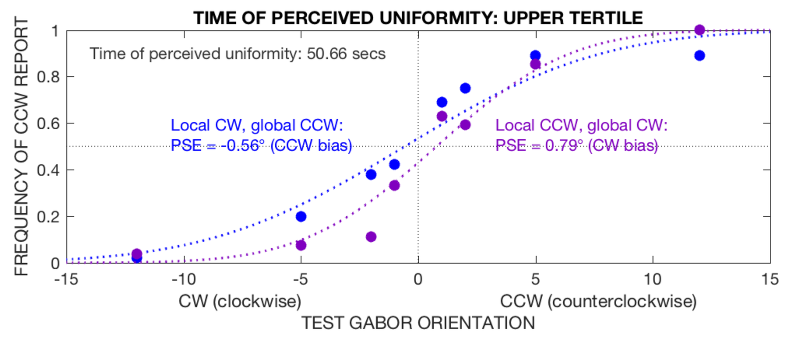
ILLUSION SESSION: ILLUSORY UNIFORMITY

REPORTS BY ADAPTING ORIENTATIONS



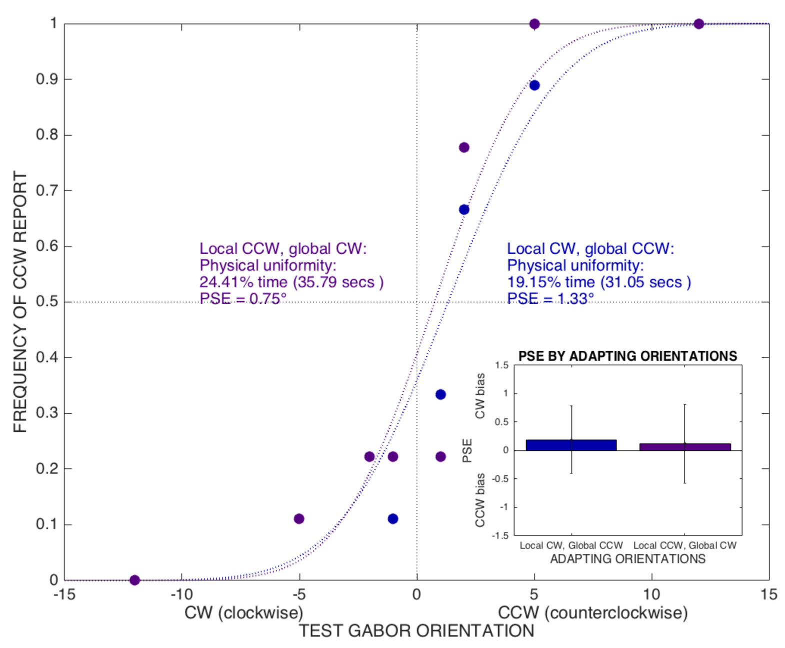
REPORTS BY ADAPTING ORIENTATIONS AND TIME OF PERCEIVED UNIFORMITY



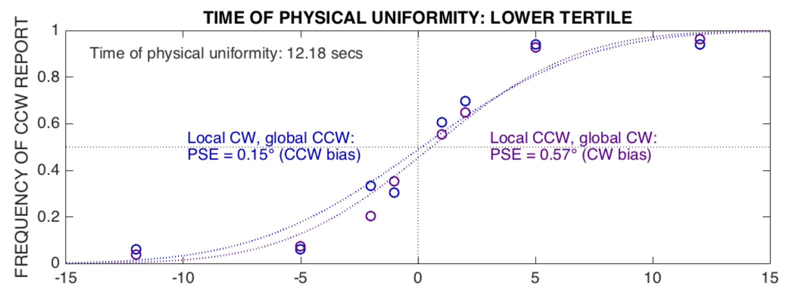


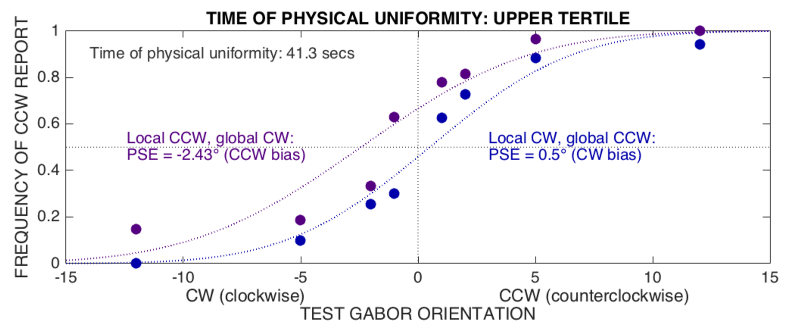
CONTROL SESSION: PHYSICAL UNIFORMITY

REPORTS BY ADAPTING ORIENTATIONS



REPORTS BY ADAPTING ORIENTATIONS AND TIME OF PHYSICAL UNIFORMITY



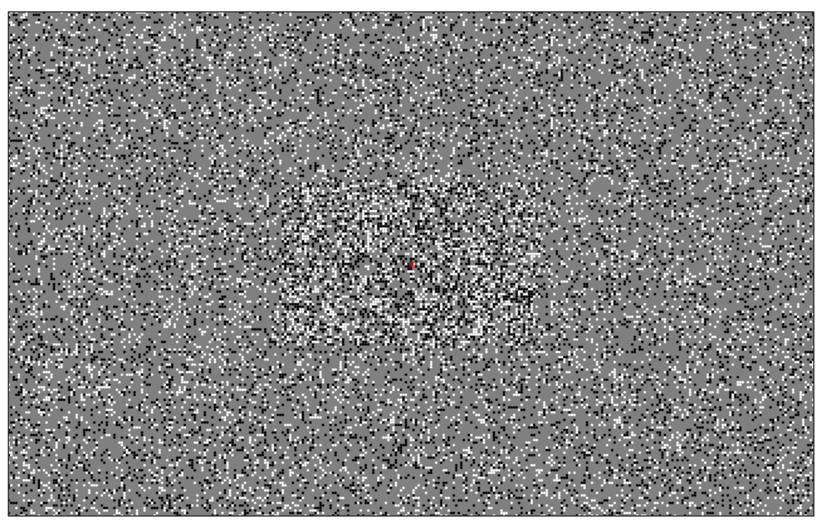


The tilt after-effect follows the local, physically presented orientation rather than the global orientation perceived under the illusion of uniformity. This was not due to insufficient exposure to the global pattern to produce an after-effect as presentation of physical uniformity for the same durations as participant reports of the illusion did produce an after-effect to the global orientation.

2. UNIFORMITY ILLUSION ON SPATIAL DENSITY

2.1. METHODS

ADAPTATION PHASE (120 SECONDS)



During the **adaptation phase**, participants are presented with a pattern with higher spatial density in the center than the periphery (**Dd**). Some control blocks have uniformly high (**DD**) or low (**dd**) density. In Dd blocks, under the uniformity illusion, phenomenology should be equivalent to pattern DD.

In the **control session**, Dd pattern is replaced by DD at the times in which participants reported the illusion in the previous session.

TEST PHASE (0.5 SECONDS PER STIMULUS)

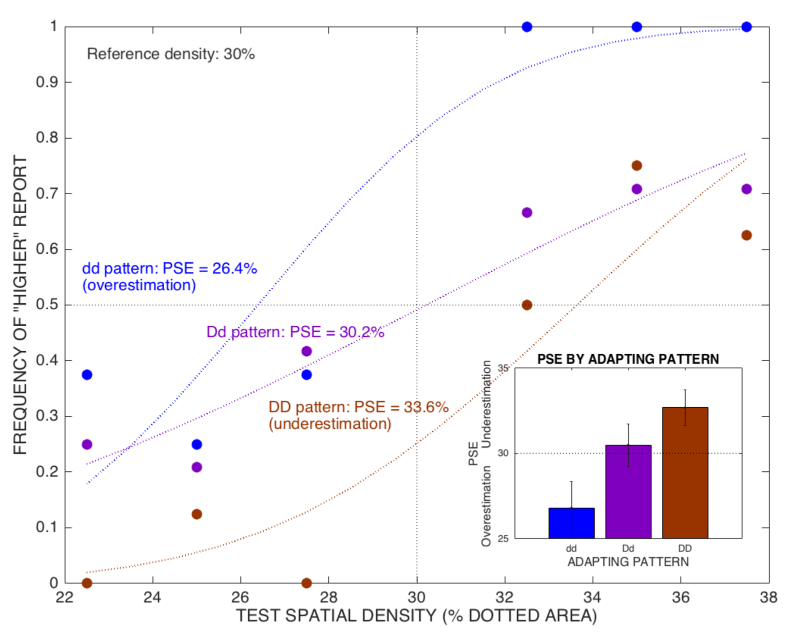
Experiment 2A: Internal reference. Appearance test. Participants report if the density of a peripheral circle is lower or higher than a reference previously learnt. If the uniformity illusion has any effect, responses after exposure to Dd should be more similar to those after DD the longer the illusion has been reported.

Experiment 2B: External reference – 2AFC. Performance (discrimination) test. Participants select, between two peripheral circles, the one with higher density. If the illusion has any sensory effect, responses after Dd should be more similar to those after DD in relation with the time of uniformity.

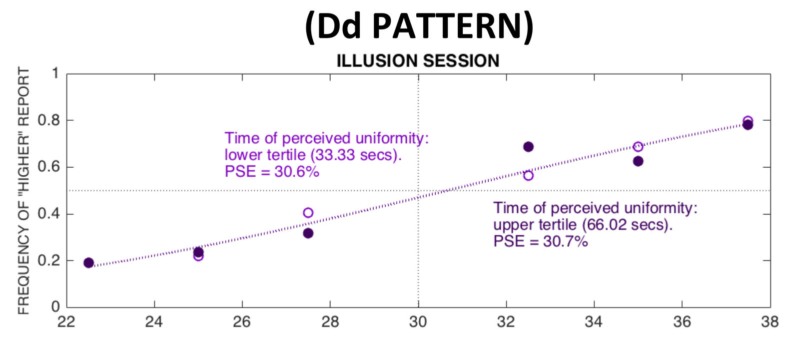
2.2. RESULTS

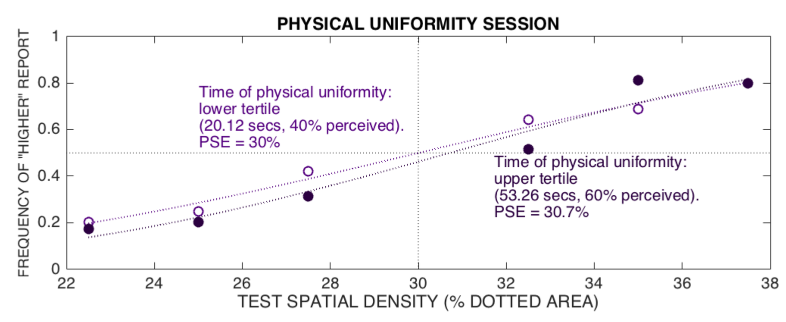
EXPERIMENT 2A : INTERNAL REFERENCE DENSITY

REPORTS BY ADAPTING DENSITIES (ILLUSION SESSION)



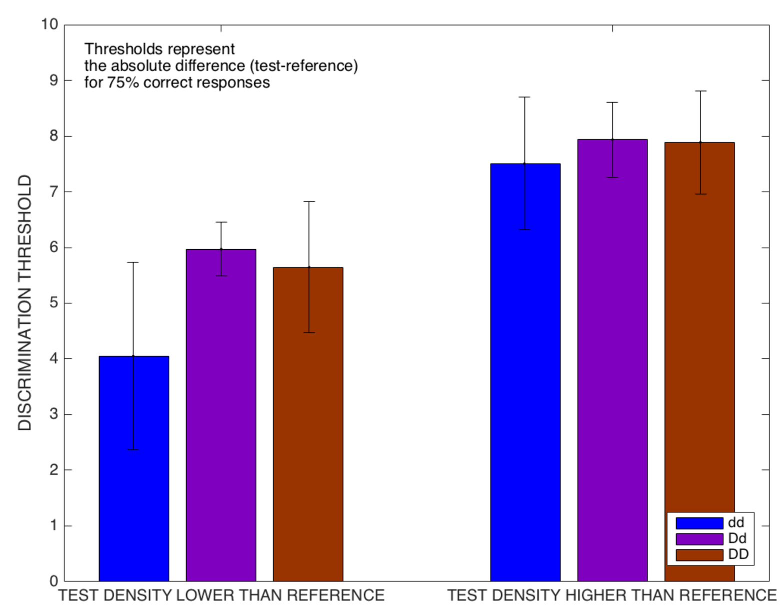
REPORTS BY TIME OF UNIFORMITY (Dd PATTERN)



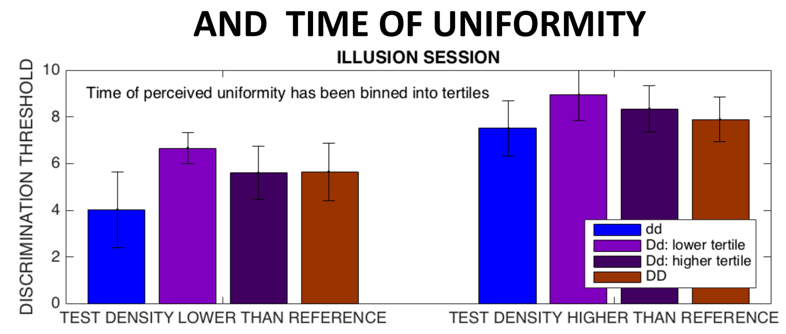


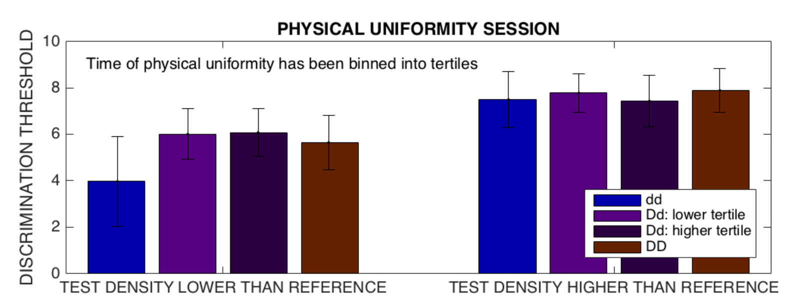
EXPERIMENT 2B : EXTERNAL REFERENCE DENSITY (2AFC TASK)

DISCRIMINATION BY ADAPTING DENSITIES (ILLUSION SESSION)



DISCRIMINATION BY ADAPTING DENSITIES AND TIME OF UNIFORMITY





The intermediate level of responses following exposure to illusory uniformity are consistent with perception having been adapted to the illusory percept. However, as magnitude of effect does not vary with reported time of illusion exposure, this seems unlikely. Rather, the data is consistent with a non-local effect of the high density central display.

DISCUSSION: Experiments performed on two visual domains indicate that the uniformity illusion is not associated with a change in the sensory encoding on a local basis. While it might directly modify more abstract dimensions (such as numerosity, akin to our formalization of spatial density), the time invariance of the effect makes alternative explanations more likely and therefore, suggests that the uniformity illusion arises from high-level perceptual processes.

[1] *Otten M, Psychological Science 2016.*