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It's all in your head: Expectations create illusory perception in a dual-task setup

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ABSTRACT

Predictions about the world can guide our perception and action, but they can also misguide us. We developed novel dual-task setups where the participants are occupied by a primary task and are from time to time queried about the phenomenal contents of the auxiliary task. We show that "hallucinating" the presence of an actually absent stimulus is not an exception, but a common phenomenon (more than 90% of participants experienced illusory objects at least once). Additionally, in experiment 1 we found a negative correlation between the amount of illusory perceptions and the Autism Spectrum Quotient score. People who scored higher on the questionnaire, were less likely to experience illusory objects. Finally, we observed no effect of spatial attention on expectation-based illusory presence of an object. More generally our results demonstrate that expectations misguide perception when attention is diverted to another task.

1. Introduction

It is well known that prior knowledge can have not only positive but also negative effects on memory (Loftus, 2003). For example, people can falsely remember objects that were not on the scene or words that were actually not included in the learned list (Roediger & McDermott, 1995). Similarly, it has been shown that prior knowledge can create perceptual illusions of object or feature presence. For example, it has been demonstrated that prior knowledge can lead the participants to hear tones that were not played and see letters on a screen that objectively was blank: expectation can create something in the place of nothing (Aru & Bachmann, 2017; Kuhn & Rensink, 2016; Mack, Erol, Clarke, & Bert, 2016; Powers, Mathys & Corlett, 2017; Tompkins, Woods, & Aimola Davies, 2016).

These findings are well in line with the general idea that our conscious perception is a mixture of and depends on both sensory data and prior knowledge. This intuition has been formalized in predictive coding models of perception, which suggest that perception is determined by the relative weighting of sensory data and expectations (Clark, 2015; Friston, 2005; Hohwy, 2013; O'Callaghan, Kveraga, Shine, Adams, & Bar, 2017). Any manipulation of this relative weighting will affect whether perception depends more on actual sensory evidence or on prior knowledge. For example, previous research has shown that prior knowledge dominates perception when the sensory data is degraded (2016; Aru et al., 2012; Powers et al., 2017) or ambiguous (Sterzer, Frith & Petrovic, 2008; Weilnhammer, Stuke, Sterzer, & Schmack, 2018) or when there is a strong prior (Kuhn & Rensink, 2016; Tompkins et al., 2016).

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One factor that influences the reliability of sensory data is attention: effects of attention on neural processing and the concomitant behavior have been shown throughout the cortex in humans and monkeys (e.g. Maunsell & Treue, 2006). Attention typically improves veridicality of perception and lack of attention may impair perception. Accordingly, it has been demonstrated that expectations bias perception when attention is diverted away from the stimuli (Aru & Bachmann, 2017; Mack et al., 2016). In these experiments participants were in a dual-task setting, where they were more often asked about stimuli relevant for one task and only rarely about the stimuli relevant for the other task. On some trials stimuli were completely omitted in the rare task, but the participants were nevertheless prompted to answer questions about these actually absent stimuli. It was observed that roughly half of the participants start typing in the letters that were actually not on the screen (Mack et al., 2016) and rate the visibility of these non-existent letters as if they had actually perceived them (Aru & Bachmann, 2017). In the terms of predictive processing these effects can be explained by saying that the way attention is deployed modulates the precision of the sensory data (Clark, 2015; Feldman & Friston, 2010; Hohwy, 2013): if attention is drawn away, the relative weighting of prior expectation over sensory data increases. In other words, when attention is directed away from the stimuli, expectations dominate in forming the percept.

Here we extend this line of research in three important respects. First, we try to better understand why some participants perceive illusory stimuli and others do not. In previous works, 40–50% of participants perceived illusory stimuli while others noticed that the stimulus was actually absent (Aru & Bachmann, 2017; Mack et al., 2016). To better understand the differences between the participants, we use in Experiment 2 two different experimental paradigms on the same participants. This allows us to correlate the values of illusory perception across tasks. Are the participants who perceive illusory stimuli in one task more likely to perceive illusory stimuli in another task? Is the propensity to “hallucinate” a trait or task-dependent state? We include the Autism Spectrum Quotient (AQ, Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) for measuring autism-like traits in a subclinical population. It has been suggested that an imbalance between priors and prediction errors is at the core of autistic traits, more specifically that autism is related to an overweighting of prediction errors (Lawson, Rees & Friston, 2014; Pellicano & Burr, 2012; van de Cruys et al., 2014). These theoretical ideas are at least partly motivated by experimental data showing that autistic participants tend to exhibit reduced susceptibility to certain illusions (Happé, 1996; Pellicano & Burr, 2012; van de Cruys et al., 2014). Extrapolating these findings to our experimental setup we predict that participants with higher scores on the AQ will experience less illusory perception. In other words, we expect that part of the interindividual differences in illusory perception can be explained by the score on the AQ.

Second, we try to better understand the necessary ingredients of an experimental paradigm that is designed to elicit illusory perception. For example, some previous works used a modification of the classic iconic memory paradigm of Sperling (Aru & Bachmann, 2017; Mack et al., 2016) with auditory post-cues. However, it is unclear whether these post-cues are required to generate illusory perception and our preliminary results suggested that they are not (Aru & Bachmann, 2017). In order to separate our task from the standard iconic memory task we included the auditory tone cue in only one of the tasks, but not in others: if illusory perception can also be elicited without these auditory post-cues then we know that they are not crucially contributing to eliciting illusory perception.

Third, we try to understand what type of attention this illusory perception is dependent on. Attention plays a significant role in perception, as it can enhance the perception of attended objects or even result in failure to perceive unattended objects when attention is diverted away (e.g., inattentional blindness). In previous experiments (Aru & Bachmann, 2017; Mack et al., 2016) spatial attention and feature-based attention have been confounded. Here, in experiment 1 we use a task where we explicitly manipulate spatial attention. Specifically, we ask whether spatial attention has an effect on the subjective visibility of attended versus unattended stimuli when they are actually missing from the display.

2. Methods

2.1. Apparatus and general procedure

For the computer-controlled experimental display a SUN CM751U CRT monitor with 1024 × 768 pixels resolution and 100 Hz refresh rate was used. The experiments were programmed and run on VisionEgg. In all experiments the observers viewed the arrays from a distance of 80 cm.

In all experiments the participants were confronted with a dual task in the main block. In this dual-task setup one task was the “main task”, the other task the “auxiliary task”. On 90% of the trials the participants were queried about the stimuli in the main task, but they were told from the outset that the auxiliary task is also relevant. Participants were always trained on both the main task and the auxiliary task separately before the dual task condition. After finishing the experiment(s), participants were debriefed about their experience and asked if they had noticed the missing stimuli.

2.2. Experiment 1

2.2.1. Participants and stimuli

Sixteen participants (6 male, 10 female) participated in experiment 1. Participant ages ranged from 18 to 25 years old ($M = 21.38$, $SD = 1.9$). Two participants were left-handed. All had normal or corrected to normal vision. We excluded two participants: one claimed at the debriefing that he had ignored the central cue. The other said that he had explicitly tried to observe the auxiliary task stimulus. In both experiments the sample size was determined by pragmatic considerations.

Face stimuli used in experiments 1 and 2a were selected from the Radboud Faces Database (Langner et al., 2010). To ensure uniformity of stimuli, all images were transformed to grayscale and resized to fit a round shape of uniform size, removing the hairline