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Perceived duration decreases with increasing eccentricity

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ABSTRACT

Previous studies examining the influence of stimulus location on temporal perception yield inhomogeneous and contradicting results. Therefore, the aim of the present study is to soundly examine the effect of stimulus eccentricity. In a series of five experiments, subjects compared the duration of foveal disks to disks presented at different retinal eccentricities on the horizontal meridian. The results show that the perceived duration of a visual stimulus declines with increasing eccentricity. The effect was replicated with various stimulus orders (Experiments 1–3), as well as with cortically magnified stimuli (Experiments 4–5), ruling out that the effect was merely caused by different cortical representation sizes. The apparent decreasing duration of stimuli with increasing eccentricity is discussed with respect to current models of time perception, the possible influence of visual attention and respective underlying physiological characteristics of the visual system.

1. Introduction

Driving a car, crossing a busy street or scoring a goal — in all those everyday situations it is crucial to properly judge the duration of short events (e.g. Binkofski & Block, 1996; Wittmann, 2009). Nevertheless, it is well known that the subjective duration is influenced by nontemporal characteristics of the stimulus (for reviews see Buhusi & Meck, 2005; Eagleman, 2008; Eagleman & Pariyadath, 2009; Grondin, 2010) like size (Ono & Kawahara, 2007; Thomas & Cantor, 1975; Xuan, Zhang, He, & Chen, 2007), predictability (Matthews, 2011; Pariyadath & Eagleman, 2007; Tse, Intriligator, Rivest, & Cavanagh, 2004; Ulrich, Nitschke, & Rammsayer, 2006), or the direction of the observer's attention (Chen & O'Neill, 2001; Cicchini & Morrone, 2009; Enns, Brehaut, & Shore, 1999; Mattes & Ulrich, 1998; Seifried & Ulrich, 2011; Yeshurun & Marom, 2008). Since each visual stimulus is processed at a specific location of the retina and the retina is not homogenous in nature (e.g. Westheimer, 1984), it seems of particular importance to answer the question of whether and how the retinal location of a stimulus affects duration estimation.

In general, there is broad consensus that various performance measures like object discrimination (Berkley, Kitterle, & Watkins, 1975; Lewis, Rosén, Unsbo, & Gustafsson, 2011; Virsu & Rovamo, 1979), object detection (Plainis, Murray, & Chauhan, 2001; Weber & Rau, 1992), as well as reaction times (Ando, Kida, & Oda, 2001; Tsal, 1983; Wall, Maw, Stanek, & Chauhan, 1996) systematically differ for central and peripheral stimuli. Furthermore, it has been found that the performance in object recognition and scene categorization (Boucart, Moroni, Thibaut, Szaffarczyk, & Greene, 2013; Boucart, Naili, Despretz, Defoort-Dhellemmes, & Fabre-Thorpe, 2010) declines with increasing stimulus eccentricity. However, there exist only a few studies examining temporal perception depending on eccentricity (Aedo-Jury & Pins, 2010; Long & Beaton, 1981; Roussel, Grondin, & Killeen, 2009; Westheimer, 1983). Even more disaffecting, these studies yield rather different results: In a temporal order judgment (TOJ) task, Westheimer (1983) reported remarkably constant threshold values for pairs of simple line stimuli presented between 2.5° and 20° eccentricities and thus concluded that time perception is independent of the stimulus location. However, when subjects verbally categorized 40 and 70 ms white disk stimuli into 'short', 'medium' and 'long', Long and Beaton (1981) found that perceived duration increased with increasing retinal eccentricity of the stimulus (0°, 2° and 4°). In contrast, Aedo-Jury and Pins (2010) showed a significant compression of duration with increasing stimulus eccentricity. In their study, subjects rated the duration of two empty intervals. The probe interval was marked by a pair of successive flashes, one presented 6° above and the other 6° below fixation. Flashes defining the comparison interval had the same vertical position, but their horizontal position varied from 0° to 48° eccentricities.

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Yet, there is a growing body of literature showing that time perception is strongly dependent on task and stimulus characteristics (for reviews see Buhusi & Meck, 2005; Eagleman, 2008; Eagleman & Pariyadath, 2009; Grondin, 2010). Obviously, the three aforementioned studies examining effects of stimulus eccentricity differ in a variety of these characteristics. For example, in the most recent work by Aedo-Jury and Pins (2010) the on- and offset of the time interval were marked by short flashes presented at various locations (i.e. a seemingly moving, empty interval) whereas Long and Beaton (1981) used stationary disks as stimuli. Since two separate events have to be encoded when timing an empty interval, the task used by Aedo-Jury and Pins (2010) might seem more complex and thus more distortable than timing a filled interval. Furthermore, also the kappa-effect (Jones & Huang, 1982; Masuda, Kimura, Dan, & Wada, 2011) or previous fixation and the direction of the illusory movement (Roussel et al., 2009) might have affected their results.

Thus, the aim of the present study is to soundly examine the effect of stimulus eccentricity on perceived duration in a series of experiments using simple stationary stimuli.

This seems of particular interest, since each visual stimulus is processed at a certain retinal location, and in many research paradigms eccentric stimuli are used without detailing possible influences of stimulus eccentricity (e.g. Mattes & Ulrich, 1998; Seifried & Ulrich, 2011).

In a series of five experiments, observers compared the duration of two stationary disks, one presented foveally, the other in the periphery. Various sequences with changing serial order, or location of standard and comparison stimuli were realized in Experiments 1 to 3. Effects of cortical magnification (e.g. Rovamo & Virsu, 1979) were investigated in Experiments 4 and 5.

2. Experiment 1

In Experiment 1, we examined whether the eccentricity of a simple stationary visual stimulus affects its perceived duration compared to an otherwise identical foveal stimulus in a forced choice reminder task that is also called method of constant stimuli. In this task, one of the two presented stimuli is always the same and serves as a reminder or standard that is not judged, but may improve performance (Macmillan & Creelman, 2005). Regarding the research reviewed in Section 1 Introduction, there is mixed evidence on effects of eccentricity and perceived duration: On the one hand, stimulus location did not influence time perception (Westheimer, 1983), and on the other perceived duration increased with increasing stimulus eccentricity (Long & Beaton, 1981). Moreover, it was observed that perceived duration decreased with increasing eccentricity (Aedo-Jury & Pins, 2010). Hence, the aim of Experiment 1 was to clarify the role of eccentricity in perceived duration.

2.1. Methods

2.1.1. Participants

Ten naïve subjects with normal or corrected-to-normal vision were recruited from the population of undergraduate students of Ulm University (9 female, age $M = 21.6$, $SD = 2.17$), and received partial course credit for their attendance. All gave informed consent to their participation.

2.1.2. Apparatus

The experiment was programmed on a Windows computer with MATLAB, Version R2009b (The MathWorks) using the software library Psychtoolbox, Version 3.0.8 (Brainard, 1997; Pelli, 1997). Stimuli were presented on a 20 in Vision Master Pro 512 monitor (1152 × 864 pixels) running at 100 Hz. A head-chin rest ensured a constant viewing distance of approximately 60 cm, at which the display subtended 36.87° by 28.07°. The number block of a standard keyboard served as response device.

2.1.3. Stimuli

Stimulus material consisted of a black disk with a diameter of 0.8° presented on a gray screen (lum = 33 cd/m^2, measured by a GOSSEN MAVOLUX 5032B USB luminance meter). The disk was either presented for 120 ms at the center of the screen (standard) or for 20, 60, 100, 140, 180 or 220 ms at 3°, 6° or 9° eccentricity left or right of fixation (comparison). These brief stimulus durations ensured that eye movements could hardly occur before stimulus offset (Mayfrank, Kimmig, & Fischer, 1987) and helped to avoid explicit counting, which becomes a supporting strategy for judging stimuli of more than 1.2 s (Grondin, Meilleur-Wells, & Lachance, 1999).

2.1.4. Procedure

The experiment was run in a single session of about 50 min. At first, participants were instructed verbally and in written form. Then, a practice block including 24 trials was executed. In each of the 3 (eccentricities) × 2 (visual fields) × 6 (durations) conditions, 15 repetitions were performed resulting in 540 ratings per observer. To prevent artifacts due to eye strain or fatigue, the testing was split in three equal blocks of five trials per condition with breaks of about 5 min between the blocks. Presentation order was randomized within a block.

At the beginning of each trial, a black fixation cross (1.6° × 1.6°, 0.1° linewidth) with an empty center (0.8° × 0.8°) was presented in the center of the otherwise gray screen. In order to discourage rhythmical answering strategies, its duration was randomly drawn from a normal distribution with $M = 500$ ms and $SD = 25$ ms within fixed limits ($min = 100$ ms, $max = 900$ ms). After a blank interval of 200 ms, the standard was presented and followed by the comparison after an ISI of 200 ms. Importance of steady fixation at the screen center during the whole trial was emphasized to the observers by explaining that this was the ideal strategy to solve the task with bilateral presentation. Furthermore, they were instructed to compare the durations of the two disks by pressing the key ‘1’, if the first stimulus (standard) was judged to have lasted longer and the key ‘2’ if the second stimulus (comparison) appeared to have lasted longer. The key press started a new trial. An illustration of the trial sequence is given in Fig. 1.

2.1.5. Analysis

Data analysis was performed using MATLAB, Version R2009b (MathWorks, Inc.) and PASW SPSS 18 (IBM, SPSS Inc.). The percentage of the rating ‘standard longer’ in the different conditions was calculated as dependent variable. The point of subjective similarity (PSS, 50% threshold) was determined by fitting an inverted logistic function to the observed relation between the dependent variable and the duration of comparisons, separately for each subject for each eccentricity (3°, 6° and 9°; compare Matthews, 2011). This procedure is graphically illustrated in Fig. 2. If the objective and the subjective durations coincide, the PSS should be equal to 120 ms, i.e. the duration of the standard

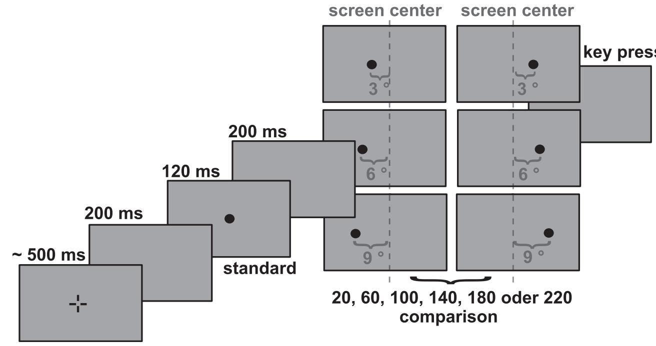

Fig. 1. Illustration of the sequence of events in Experiment 1. The trials differed according to eccentricity, visual field and duration of the comparison stimulus. Gray markings are just for illustrational purposes and do not appear on the presented screens.