THE EBBINGHAUS ILLUSION MODULATES THE DETECTION OF SIZE-DEFINED TARGETS IN VISUAL SEARCH

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Abstract

The experiments reported in this chapter investigated whether objects' apparent size, unlike their retinal size, is coded in pre-attentive vision. Observers searched for a target test circle that was either larger or smaller than the distractor test circles, with both types of test circle surrounded by context circles modulating their apparent size (Ebbinghaus illusion). The size ratio between the test and context circles was manipulated such that, for example, the test circles were surrounded by smaller context circles (making, e.g., the larger target appear even larger) or by larger context circles (making, e.g., the smaller distractors appear even smaller). These experimental conditions were contrasted with control conditions without context circles, in which the retinal size of the test circles corresponded to the apparent size of the test circles in the experimental conditions. The search times were independent of the number of Ebbinghaus configurations in the display, and the Ebbinghaus apparent-size illusion modulated the search times in a manner similar to the retinal size manipulation in the control conditions. Taken together with earlier findings (Busch & Müller, 2000), this pattern of results is consistent with pre-attentive, efficient processing of objects' apparent size.

In visual search, a target object that differs from the distractor objects in retinal size can be discerned efficiently, that is, the search reaction times (RTs) are independent of the number of items in the search display (e.g., Müller, Heller, & Ziegler, 1995). This finding supports the conclusion of spatially parallel, pre-attentive processing of retinal object size. In a series of search experiments, we (Busch & Müller, 2000; 2001) investigated whether display objects' apparent size, too, is derived and represented pre-attentively (similar to their retinal size). The experiments varied the objects' apparent size by introducing the geometric-optical 'Ebbinghaus' illusion. This figure, described by Ebbinghaus (1913), consists of an inner test circle surrounded by several context circles. Smaller context circles make the test circle appear larger than an identical comparison circle, whereas larger context circle make the test circle appear smaller (Figure 1). The magnitude of the misjudgement increases with increasing size difference between test and context circles (Massaro & Anderson, 1971).
Previous search experiments showed that, under optimal conditions, with the (to-be-detected) target test circle being larger than the distractor test circles, RTs were independent of the number of Ebbinghaus figures in the display and, importantly, that the manipulation of apparent size by smaller context circles can facilitate the detection of the target in comparison with a control condition without context circles (Figure 2). In contrast, RTs were slowed when test circles were surrounded by larger context circles, perhaps because the size of the target test circle was 'in-between' the size of the distractor test circles and that of the context circles and therefore harder to detect (Wolfe, 1998).

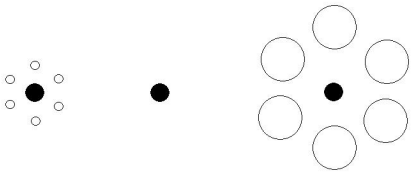

Figure 1. Ebbinghaus illusion.

The expedited detection RTs for target test circles surrounded by smaller context circles can be explained by assuming that the manipulation of the test circles' apparent size reinforces the (retinal) size difference between target and distractor test circles, thereby increasing the saliency of the target. The two experiments reported below were designed to test this assumption. In Experiment 1, a psychophysical experiment, we determined the apparent sizes (the magnitude of misjudgement) of the test circles in the search conditions used by Busch and Müller (2000). These estimated parameters were then introduced as direct control conditions in Experiment 2, a visual search experiment. If the expedited detection of a target test circle surrounded by smaller context circles can in fact be attributed to a pre-attentive representation of the test circles' apparent size, the efficiency of target detection under control conditions (without context circles) should directly correspond with that under experimental conditions (with context circles, i.e., with the influence of the size illusion).

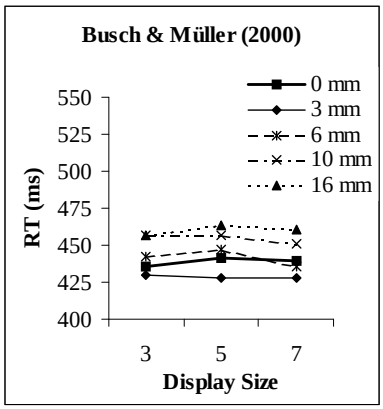

Figure 2. Results of Busch & Müller (2000).

Experiment 1: Method

Twenty four observers participated in Experiment 1. Their task was to decide, on each trial, which of two filled black circles – the test circle surrounded by six outlined context circles or

a comparison circle without context circles – was the larger circle (Figure 3). In line with the parameters in the search experiments of Busch and Müller (2000; 2001), test circles were either 6 or 10 mm and context circles either 3, 6, 10, or 16 mm in diameter. The corresponding comparison circles were varied in steps of 0.5 mm between 3 and 9 mm or between 9 and 13 mm, for 6-mm and 10-mm test circles, respectively.

Figure 3. Example display in the psychophysical Experiment 1.

Experiment 1: Results and Discussion

Figure 4 presents the frequencies of the responses 'test circle larger than comparison circle' as a function of the size of the comparison circle for the four context-circle sizes, separately for two test-circle conditions. In a particular experimental condition, a test circle's apparent size was estimated as the size of the comparison circle for which the response frequency was 50% (i.e., the 'point of subjective equality'). For instance, a 6-mm test circle appeared 6.30 mm in diameter when surrounded by 3-mm context circles, but 5.63 mm in diameter when surrounded by 16-mm context circles. A 10-mm test circle appeared 10.25 mm in diameter when surrounded by 3-mm context circles, but 9.13 mm in diameter when surrounded by 16-mm context circles.

Thus, the apparent size of the test circles varies according to the size of their surrounding context circles. A test circle surrounded by smaller context circles appears larger, whereas a test circle surrounded by larger context circles appears smaller (Ebbinghaus illusion). Table 1 summarizes the parameters of the test circles introduced in the control conditions of the subsequent visual search experiment (Experiment 2).

Table 1. Apparent sizes of test circles as judged in Experiment 1, that served as parameters for Experiment 2.

Context Circles (mm)	Test Circles (mm)	
	6	10
0	6.12	10.00
3	6.30	10.25
6	5.80	10.10
10	5.75	9.70
16	5.63	9.13

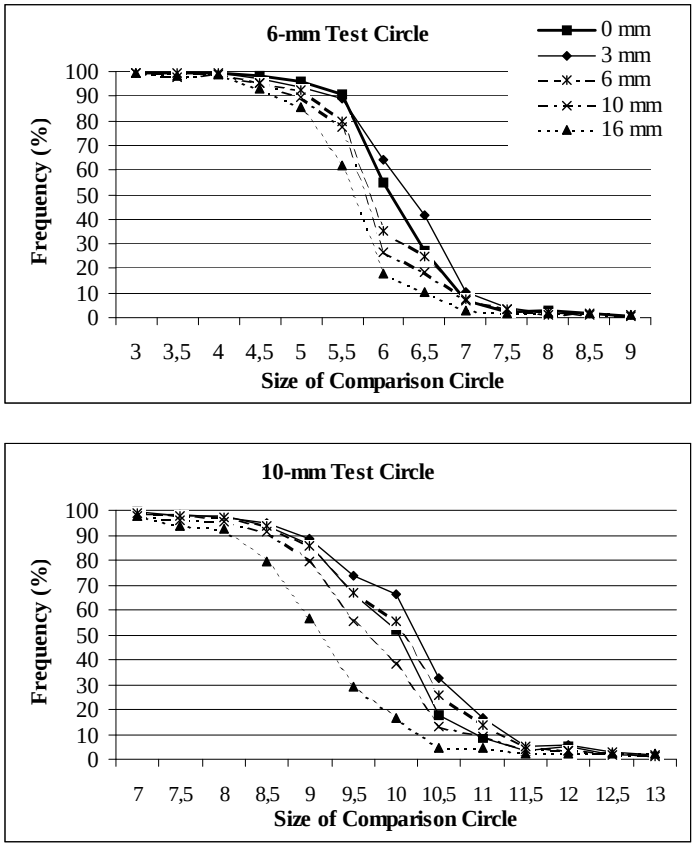

Figure 4. Results of Experiment 1.

Experiment 2: Method

12 observers participated in Experiment 2. Search displays consisted of three, five, or seven test circles with or without context circles, respectively (Figure 5). For each experimental condition (with context circles), a corresponding control condition (without context circles) was realized, in which the retinal size of the test circles (i.e., of both the target and the distractor test circles) was matched with the apparent size of the test circles in the experimental conditions.

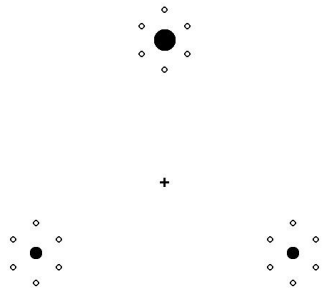

Figure 5. Example display in the visual search Experiment 2.

Experiment 2: Results

Figure 6 presents the group mean target-present search RTs as a function of the number of items in the display (the 'display size'), separately for the experimental and control conditions. Under both conditions, the search RT functions were independent of the display size, providing evidence of efficient target detection.

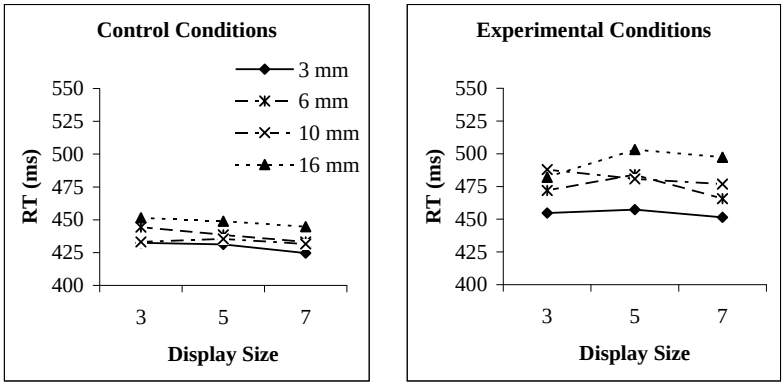

Figure 6. Results of Experiment 2.

The results of the experimental conditions confirm the results of our previous search experiments (Busch & Müller, 2000, 2001): Search for a large target test circle amongst smaller distractor test circles proceeds faster when test circles are surrounded by smaller context circles than when they are surrounded by larger context circles.

In the corresponding control conditions, search RTs exhibited a very similar pattern to the experimental conditions: under control conditions that matched the experimental conditions with smaller context circles, RTs were faster than under control conditions that corresponded with experimental conditions with larger context circles.

Experiment 2: Discussion

This pattern of results confirms that visual search for an 'apparently' larger target object proceeds independently of display size (Busch & Müller, 2000, 2001). Flat search RT functions indicate that the apparent size of target and distractor objects is derived pre-attentively.
The pattern of RTs in the experimental and control conditions exhibited very similar trends, indicating that visual search performance in the experimental conditions was influenced by the manipulation of the test circles' apparent size. However, RTs in the experimental conditions were some 30 ms slower compared to the control conditions. This suggests that, under experimental conditions, the search involves additional processes, most likely suppression of the task-irrelevant context circles. Suppression of the context circle may be necessary because, while giving rise to the Ebbinghaus apparent-size illusion facilitating the search, they also act as harmful 'distractors' diverting size comparisons away from the test circles. Consistent with this, we (Müller & Busch, 2001) have found that, when the context circles are presented prior to the test circles permitting them to be suppressed in advance, the distracting effect of the context circles are reduced along with their facilitatory effects.

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References

Busch, A., & Müller, H.J. (2000). Visuelle Suche nach größendefinierten Targetobjekten bei der Ebbinghaus-Illusion: Evidenz für präattentive Verarbeitung scheinbarer Objektgröße. In H. Bülthoff, M. Fahle, K. Gegenfurtner, & H. Mallot (Eds.), *Beiträge zur 3. Tübinger Wahrnehmungskonferenz,* Knirsch Verlag: Kirchentellinsfurt.

Busch, A., & Müller, H.J. (2001). The Ebbinghaus illusion modulates visual search for size-defined targets: Evidence for pre-attentive processing of apparent object size. *Perception & Psychophysics* (under revision).

Ebbingbaus, H. (1913). *Grundzüge der Psychologie*. Leipzig, Verlag von Veit und Co.

Massaro, D.W., & Anderson, N.H. (1971). *Judgemental model of the Ebbinghaus illusion*. Journal of Experimental Psychology, 89, 147-151.

Müller, H.J., & Busch. A. (2001). *Visual search for size-defined targets in the Ebbinghaus illusion: Facilitory and inhibitory effects of the search context* (unpublished manuscript).

Müller, H.J., Heller, D., & Ziegler, J. (1995). Visual search for singleton feature targets within and across feature dimension. *Perception & Psychophysics*, 57, 1-17.

Wolfe, J. (1998). Visual search. In H. Pashler (Ed.), *Attention* (pp. 13-73). Hove (UK): Psychology Press.