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Is the Ebbinghaus illusion a size contrast illusion?

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ABSTRACT

The Ebbinghaus illusion, in which a central target surrounded by larger context figures looks smaller than when surrounded by smaller context figures, is usually classified as a size contrast illusion. Thus "size contrast" is the dominant account of this effect. However, according to an alternative "contour interaction" account this phenomenon has little to do with size contrast but is rather caused by distance-dependent attractive and repulsive interactions between neural representation of contours. Here evidence is presented against the size contrast account and consistent with the contour interaction account. Experiment 1 was a control study confirming that the illusion can be obtained using displays consisting only of squares, which are more convenient to manipulate than the standardly used circles. In Experiment 2, the standard configuration involving small context figures surrounding the target was compared to a novel configuration, which involved many "spread" small context figures. The illusory effect of the standard context was stronger than the illusory effect of the spread context, in accord with the prediction of the contour interaction account, and contrary to the prediction of the size contrast account. In Experiment 3 two novel configurations were used, based on standard and spread contexts. The results were in accord with the prediction of the contour interaction account, whereas the size contrast account had no prediction because the stimuli did not involve conventional size contrast. Additional aspects of the stimuli and an account of the illusion based on a perspective interpretation are also discussed.

1. Introduction

The Ebbinghaus illusion, the traditional version of which is presented in Fig. 1, is usually described as follows: the two central figures (targets) are identical, but the target surrounded by smaller figures looks larger than the one surrounded by larger figures. There is an abstract similarity of this phenomenon and the well-known lightness (or brightness) contrast illusion, in which a gray figure centered in a black surround looks lighter than the same figure on a white surround. The similarity involves both the geometrical structure of the display (target vs. surround) as well as the direction of the effect (the appearance of the target tends to shift away from the surround). Thus, it seems quite straightforward and plausible to label the Ebbinghaus illusion as a size contrast illusion, as has been done by many researchers (Aglioti, DeSouza, & Goodale, 1995; Coren & Miller, 1974; de Fockert, Davidoff, Fagot, Parron, & Goldstein, 2007; Gold, 2014; Haffenden, Schiff, & Goodale, 2001; Massaro & Anderson, 1971; Silverstein et al., 2013; Sperandio, Lak, & Goodale, 2012; Vuk & Podlesek, 2005; Yamazaki, Otsuka, Kanazawa, & Yamaguchi, 2010).

However, this idea has several conceptually problematic aspects. For one, is "size contrast" a description ('the target which is surrounded by smaller figures looks larger, and vice versa') or an explanation ('one target looks larger *because* it is surrounded by smaller figures, and vice versa')? If it is an explanation, then it should be supported by a corresponding theory accounting for the *direction* of the effect. To explain, note that in the achromatic domain one finds not only lightness contrast effects but also lightness assimilation effects, in which the lightness of the target does not get less but more similar to the background (Helson, 1963; Murgia et al., 2016); a theory of lightness should predict which of the two effects, contrast or assimilation, will appear in which contexts and why. In the domain of size perception, the possibility of size assimilation (the target surrounded by smaller figures looks *smaller*, and vice versa) sounds a priori as plausible as size contrast, and a theory of size perception should explain why it is size contrast rather than size assimilation that is usually evoked by the Ebbinghaus display; interestingly, an assimilation-type tendency was reported in an animal study using the Ebbinghaus configuration (Nakamura, Watanabe, & Fujita, 2014). In sum, it seems more appropriate to regard "size contrast" primarily as a description of the effect, or perhaps as a place holder for an explanation, unless and until an account is offered as to why the effect takes the form of contrast rather than of assimilation. One such account, based on perspective, will be discussed in the Discussion

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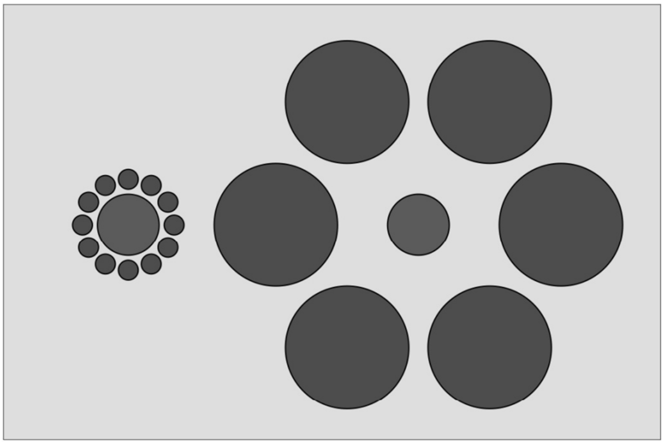

Fig. 1. A configuration that evokes the Ebbinghaus size illusion, in which the central circles look different in size although they are equal.

section.

However, there are problems in using size contrast even as a fully appropriate description. The size contrast account can be regarded as implying two separate claims: (a) the target surrounded by larger figures looks smaller than in isolation and (b) the target surrounded by smaller figures looks larger than in isolation. However, it is not necessary to invoke both of these two claims, and in these specific directions, to account for the basic fact that the target surrounded by smaller figures looks larger than the target surrounded by larger figures. This is because the same empirical outcome would follow if: (1) the target surrounded by larger figures looked smaller, but there was no contrast effect on the target surrounded by smaller figures, or if (2) the target surrounded by smaller figures looked larger, but there was no contrast effect on the target surrounded by larger figures, or if (3) both surround contexts made the targets look larger, but the effect of the smaller figures was stronger, or if (4) both surround contexts made the targets look smaller, but the effect of the larger figures was stronger. These are not just combinatorial possibilities: some results of a study of the Ebbinghaus illusion favored the account #4 (Roberts, Harris, & Yates, 2005).

Finally, and most important in the context of the present paper, there is an alternative description of the Ebbinghaus illusion as presented in Fig. 1, in which there is no mention of size of the surrounding figures at all: it says that the target that looks larger is the one whose distance from the surrounding figures is smaller, and vice versa for the other target. This alternative description suggests an alternative explanation which has nothing to do with size: nearby contours (or rather their neural representations) attract each other, whereas more distant contours repulse each other. This "contour interaction" account is the current main alternative to the "size contrast" account. The role of contours, either acting alone or in combination with size contrast, was advanced in various forms by several researchers of the Ebbinghaus illusion (Jaeger, 1978; Jaeger & Grasso, 1993; Jaeger & Klahs, 2015; Roberts et al., 2005; Rose & Bressan, 2002; Sherman & Chouinard, 2016; Weintraub, 1979; Weintraub & Schneck, 1986). Experimental attempts to control size and distance independently will be discussed in the Discussion section.

If the Ebbinghaus illusion were solely due to contour interactions, then labeling it as a "size contrast" effect would be inappropriate as an explanation, although not necessarily incorrect as a description. This is an interesting case how even an ostensibly acceptable description may not be theory-neutral, in the sense that it may (mis)lead researchers to look for explanations in certain directions and not in others. In previous studies of the Ebbinghaus illusion, figures of various shapes were used, both as targets and as contexts, but the large majority of studies used circles, such as in Fig. 1. However, in the experiments in this paper we used squares rather than circles, for a few reasons. First, there is no theoretical reason to use circles. More importantly, as argued in more detail in the Discussion section, it is not easy to define distances between circles in a completely satisfactory manner (unless they are concentric), and this becomes an issue when the theoretical focus shifts from size to distance. In this respect, squares are somewhat easier to manipulate and control than circles. Also, some of the novel types of stimuli in the experiments were easier to construct with squares than with circles. We used squares with horizontal and vertical sides, and defined their distance as the distance between their nearest parallel sides. The purpose of the first experiment was to test whether the classical illusion can be replicated with square stimuli, and also to provide baseline data. Following that, two experiments were performed which used stimulus patterns with novel types of surrounds, labeled "spread" and "merged" contexts, with the aim to confront predictions based on the size contrast account and the contour interaction account. The results present serious difficulties for the size contrast account and are broadly consistent with the contour interaction account, though they don't necessarily constitute definitive evidence for it.

2. Experiment 1

2.1. Methods

2.1.1. Subjects

18 high-school students volunteered to participate in the experiment. They were attendees of a psychology course in the Science Center in Petnica, Serbia. Participation in this and the following experiments was in accord with the Helsinki declaration.

2.1.2. Stimuli

The structure of the stimuli is presented in Fig. 2. In contrast to Fig. 1, in each display only one target (the "standard square"), presented either in the right or in the left half of the display, was surrounded by context squares, whereas the other target (the "comparison square") was isolated, and was presented in the center of the other half of the display. Half of the stimuli involved the "near/small context", in which the standard square was surrounded by 16 nearby small context squares, and the other half involved the "far/large context", in which the standard square was surrounded by 8 large, far context squares. In all stimuli, the standard square had the same angular size of 1.4°. The context squares in the near/small context had angular sizes of 0.24°, and their distance from the standard square was 0.12°. The context squares in the far/large context had angular sizes of 2.15°, and their

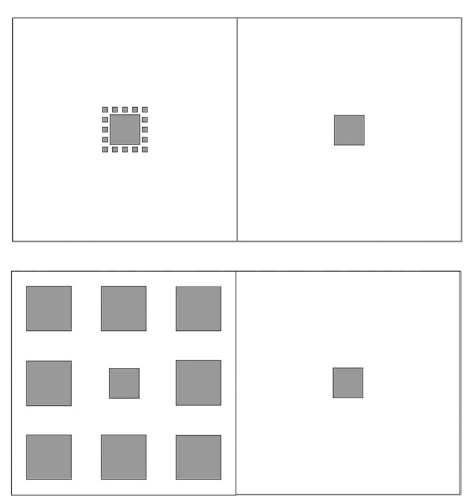

Fig. 2. Examples of stimuli used in Experiment 1. In these examples, the surrounded central square and the isolated comparison square have the same size. Top: Near/small context. Bottom: Far/large context.