Selective adaptation vs. transfer of decrement: The conjoint effects of neural fatigue and perceptual learning

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Statement of Problem

In the last few years, my colleagues and I have been interested in the processes underlying the perceived reversals of reversible figures (Long & Toppino, 1981; Long, Toppino, & Kostenbauder, 1983; Toppino & Long, 1987). One of the approaches we have used in our work is the popular *selective-adaptation* paradigm as a means by which to identify the potential role in this type of illusion of localized neural mechanisms that are subject to fatigue. In this method, an inspection figure is viewed during an adaptation period of perhaps 2-3 min, and a test figure is then shown which shares certain hypothesized features with the adaptation figure. To the extent that the prior adaptation alters the perception of the test figure, one can conclude that similar localized mechanisms are involved in the perception of both figures. This selective-adaptation paradigm has proven extremely powerful in the investigation of numerous illusions, such as the tilt aftereffect, the motion aftereffect, and the size aftereffect. Reflecting its current popularity, the selective-adaptation paradigm has been referred to as the "psychologist's electrode" (Frisby, 1980) with which to probe the tuning and response characteristics of hypothesized neural channels in the visual system (e.g., Regan, 1982).

In our work, we have attempted to demonstrate the role of localized fatigue effects on the reported reversals of the rotating Necker cube. In this illusion, a three-dimensional Necker cube frame is rotated about one of its vertices at a constant speed. An observer viewing either the cube itself or its shadow reports a striking change in the perceived direction of rotation when the cube changes its perspective. As with other reversible figures, the number of reported reversals increases and then levels off at a high rate during a 2-3-min viewing period. For several reasons, we (and others) have proposed that this changing reversal rate reflects fatigue effects in particular visual channels; in our work, we have attempted to demonstrate the limited (i.e., local) character of this fatigue by means of the selective-adaptation paradigm. In one recent experiment (Toppino & Long, 1987, Experiment 1), a rotating cube in the left (or right) visual field was viewed for a 2-min adaptation period, which was followed immediately by a 2-min test period with a cube in the same or

a different visual field. When the cube was viewed in the same visual field during both viewing periods, the reversal rate remained at the same high level for the test period. However, when a cube was viewed in different visual fields in the test and adaptation periods, the reversal rate for the test cube dropped to a low level indistinguishable from that exhibited when there had been no prior adaptation period. In an analogous second experiment, the size of the rotating cubes was either maintained or varied between the adaptation and the test periods. When an observer viewed the same large (or small) cube in both the adaptation and test phases, the reversal rate continued at the same high level during the test phase. However, when the size of the cube was varied (from large to small or from small to large) between the adaptation and test periods, the reversal rate for the test cube dropped to a low level indistinguishable from that exhibited when there had been no prior adaptation period. For both experiments, we concluded that the results were most parsimoniously interpreted in terms of neural fatigue produced in relatively localized mechanisms by the adaptation cube. This fatigue affected reversals of the test cube only when that cube involved the same localized mechanisms. A change in either cube location or cube size from adaptation to test period produced a shift in the underlying neural mechanisms, and new (i.e., unfatigued) mechanisms were accessed in the test period.

The procedure described above was borrowed directly from the current psychophysical literature, in which it is extremely popular; we were attempting to extend the procedure to a particular class of visual illusions, with the hope of identifying the nature of underlying processes. However, we have since become aware of the fact that the same basic procedure (under a different name, *transfer-of-decrement*) has been used for several years in the study of other visual illusions (Coren & Girgus, 1974; Coren & Porac, 1984; Porac & Coren, 1985). Most disconcerting, however, was our discovery that the findings with this procedure have been cited to support a conclusion very different from our conclusion based on our work with the selective-adaptation paradigm. The transfer-of-decrement paradigm assumes a learning basis for the initial change in the appearance of an illusion (e.g., Müller-Lyer) during a 3-5-min inspection period. That is, "perceptual learning" or changes in "strategy" are assumed to underlie the significant decrement in the magnitude of the illusion that occurs within the viewing period. For example, it has been reported that observers initially exhibit longer eye movements when inspecting the perceptually longer segment of the Müller-Lyer illusion (e.g., Festinger, White, & Allyn, 1968). If these erroneous eye movements are in some way incorporated into the length judgment, the continuous error feedback provided during prolonged inspection may permit "recalibration of the illusory percept" (Coren, Girgus, & Schiano, 1986,

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p. 207). Moreover, the determination of the types of figures to which this decrement then transfers theoretically permits some insight into the nature of the global cognitive processes underlying this type of perceptual effect.

The dilemma represented by these two classes of studies is clear. The same basic procedure is being used to support alternate interpretations. It appears that the most likely reason for the independent development and use of the adaptation/transfer procedure in such different contexts is an historical one: Largely different classes of illusions have been studied by different investigators. Unfortunately, it is extremely difficult at the present time to dismiss either class of studies as conceptually or methodologically flawed. On the one hand, the electrophysiological evidence for the existence of neural structures exhibiting fatigue and recovery characteristics similar to those suggested by the psychophysical work with the selective-adaptation procedure is well known (see Regan, 1982). On the other hand, the role of so-called top-down processes in numerous visual illusions as revealed by contextual and decisional effects appears to be equally well established (see Coren & Girgus, 1978). Consequently, it may well be that, as applied to the different classes of illusions with which the two paradigms have typically been employed, both interpretations are correct. Nevertheless, the recognition that alternate conclusions can be drawn from the same basic experimental manipulation suggests very clear areas in which caution is advisable in the use and interpretation of the paradigm. It is on these areas I wish to focus.

Implications

First, consider the possibility that both interpretations may be correct, depending on the perceptual phenomenon involved. If an illusion (or any visual phenomenon) is dependent largely on neural structures that alter their degree of activity during adaptation, then selective-adaptation effects are to be expected. Coltheart (1971) developed this argument very carefully in his often-cited paper, and, as noted earlier, this approach has become one of the most frequently used in current psychophysical work for determining both the existence and the response tuning of hypothesized "feature analyzers," "channels," or "filters" in the visual system. On the other hand, if an illusion (or any visual phenomenon) has a strong learning component that permits perceptual recalibration with increasing exposure to the stimulus, then a decrement in the magnitude of the illusion over extended viewing is to be expected. This view has been proposed by many investigators, going back to the turn of the century (e.g., Dewar, 1968; Judd, 1902; Mountjoy, 1958). More recently, Coren and his colleagues (Coren & Girgus, 1974; Porac & Coren, 1985) not only have continued this approach but have also strongly advocated its utility for separating the cognitive from the structural processes underlying various illusory phenomena. It should be emphasized that a multiprocess conceptualiza-

tion of illusions, in which not only different illusions but even a single illusion may depend upon multiple factors (both structural and cognitive), dominates current theorizing about illusory phenomena (e.g., Coren & Girgus, 1978). Hence, the ambiguity suggested here concerning the selective-adaptation/transfer-of-decrement procedure may merely reflect the complexity of the perceptual phenomena in question.

Perhaps more important, however, is the need for caution in the areas suggested above. At the most basic level is the working assumption that the simple viewing-test procedure represented by both the selective-adaptation paradigm and the transfer-of-decrement paradigm unambiguously reveals a fatigue effect or a learning effect. Rather, it appears that converging evidence from other operations is needed to distinguish between the possibilities. Either possibility—or, to further complicate matters, both possibilities—may be correct with regard to a single perceptual phenomenon. If a given perceptual effect can have multiple components, as has been suggested for the rotating cube illusion (Long et al., 1983), extended viewing may have its effect on both structural and process components. Coren and Girgus (1974) suggested certain manipulations that may permit a distinction between a perceptual learning model and a neural fatigue model. These include free versus fixed viewing, distributed versus massed training (adaptation), and long intervals between training and test periods. However, the significant impact of any one of these manipulations through a presumed learning effect does not preclude the existence of nonstatic structural variables.

In a closely related vein, the interpretation of any effect produced by manipulating a particular variable between the training (adaptation) and test period must be made cautiously. For example, consider the recent study by Porac and Coren (1985) in which the global manipulation of altering figure orientation was undertaken with the Müller-Lyer illusion between the training period and the test period. Rotating the illusion 180° essentially eliminated any transfer from the training to the test period. Porac and Coren (1985, p. 520) concluded that this result demonstrated the critical role of higher order "cognitive factors" in the illusion. However, a researcher using the other interpretive framework relating to this procedure might be inclined to suggest that such a manipulation altered the particular set of localized neural processes involved in the adaptation and test periods. (I am not arguing that the Müller-Lyer illusion does indeed result from basic channel activity; I am simply using this orientation manipulation as an example of an experimental manipulation with reasonable alternate interpretations.) As noted above, Toppino and Long (1987) varied the retinal position of a reversible figure from the adaptation period to the test period, and the lack of effect of the former on the latter was interpreted in terms of the localized character of the fatigue effects that underlie the illusion. The same basic manipulation was employed by von Grünau, Wiggin, and Reed (1984) on another version of this illu-

sion, with very similar results. Is it not possible, then, that the orientation manipulation employed by Porac and Coren, which involves positional change, could also have its effect due to changes in localized neural processes, rather than due to "global feature variation," the interpretation favored by Porac and Coren (1985, p. 519)? Perhaps a control condition in which the same Müller-Lyer figure is moved to a different retinal position for the test period (relative to a fixation bar that still permits eye movements) would help to distinguish between the alternatives. If localized processes are involved, little cross-adaptation to the new retinal position would be expected; but if more global learning processes are involved, strong transfer-of-decrement would be expected.

It should be noted that subsequent work by Coren and Porac and their colleagues (Coren et al., 1986; Porac, 1987) further strengthened the position that there is a learning basis to the decrement with the Müller-Lyer illusion. For example, Coren et al. (1986) reported that manipulations intended to increase the degree of neural adaptation during the inspection period (e.g., requiring eye fixation or including a grid of slanted lines matching the arrowhead orientations) produced no appreciable decrement of the illusion. Similarly, Porac (1987) found that changes in the nature of the neural adaptation permitted during the inspection period (e.g., binocular vs. monocular vs. alternating left/right viewing) produced no differences in the degree of illusion decrement. These studies further support the authors' original conclusions that there is a higher order learning component to the phenomenon. At the same time, however, they demonstrate rather impressively the empirical lengths that were necessary to eliminate the alternate interpretation.

Conclusions

Both the selective-adaptation paradigm and the transfer-of-decrement paradigm have been used extensively in the investigation of numerous visual phenomena. Although they employ the same basic viewing-test procedure, these two paradigms have been used to support very different conclusions concerning the nature of underlying visual processes. The selective-adaptation paradigm depends critically on the assumption that neural mechanisms are involved that become fatigued with extended viewing. The transfer-of-decrement paradigm depends critically on the assumption that perceptual learning is involved, by which the observer alters his/her information-processing strategy with practice. It is somewhat disappointing, from the standpoint of parsimony, to be unable to eliminate one of the two theoretical frameworks that can be supported by the research paradigm under discussion. Instead, the assumptions underlying both viewpoints appear reasonable and defensible from the perspective of current research and theory. That the two viewpoints result in very different interpretations of the same empirical procedure is unfortunate; nonetheless, the implications for researchers are clear. Whether it be called the transfer-

of-decrement paradigm or the selective-adaptation paradigm, the procedure does not, by itself, produce unambiguous results. Additional evidence is necessary to permit confidence in one interpretation over the other. Furthermore, researchers must be willing to conceptualize their manipulations in terms of other underlying processes. Could their manipulations be adapting underlying mechanisms, rather than providing a shift in performance due to learning (or vice versa)? This practice does reduce the presumed methodological rigor that is evidenced in current treatments of these procedures, but at the same time it also represents a more adequate appreciation of the complexities of the processes involved.

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