Perception, 2010, volume 39, pages 705 – 710

doi:10.1068/p6542

Ternus effect: Two processes or differential activation? Comments on Odic and Pratt's 2008 paper

J Timothy Petersik
Department of Psychology, Ripon College, PO Box 248, Ripon, WI 54971, USA;
e-mail: petersikt@ripon.edu
Received 5 August 2009, in revised form 22 February 2010

Abstract. Using a bistable apparent-motion display, Odic and Pratt (2008, *Perception* **37** 1790 – 1804) have recently presented data that they interpret as being inconsistent with what they call "the two-process theory". Instead, they argue, their data can be explained by the differential-activation theory along with a process they identify as "temporal summation of contrast". It is argued here that Odic and Pratt misinterpreted the two-process distinction and used a display that was too unusual to be adequately addressed by it. Further, their use of the differential-activation theory and, in particular, the temporal summation of contrast, seems problematic. It is concluded that there is little in their data and theoretical interpretation to justify rejection of the two-process approach.

1 Introduction

In its most commonly studied form, the Ternus display consists of a small number (assume three for this example) of equally spaced, horizontally arranged identical elements (eg dots). This arrangement of elements appears in at least two frames, with the elements of one frame being shifted laterally in the second by the center-to-center distance separating neighboring elements (Ternus 1926/1938). This leads to two 'overlapping' elements between frames and a single non-overlapping element that appears on the left in one frame and on the right in the other. Often there is a blank ISI frame appearing between the two stimulus frames (see Petersik and Rice 2006, figure 1). When presented in sequence, these frames lead to what Ullman (1979) called a correspondence problem: the stimulus dots can alternatively be matched across frames to produce the percept of a collective group of three that moves back and forth (group movement) or as two stationary overlapping dots with a single dot moving from end to end around the stationary ones (element movement). In fact, either percept can be produced, depending upon the exact stimulus conditions. Further, under some stimulus conditions, prolonged inspection of the display leads to alternation between the two percepts.

In the past, a variety of authors have interpreted the two alternative percepts that are produced by the Ternus display as reflecting the activity of two functionally different apparent-movement (AM) processes (eg Braddick and Adlard 1978; Pantle and Picciano 1976; Petersik 1989, 1994; Petersik and Pantle 1979). There have been challenges to the two-process distinction (eg Bischof and di Lollo 1990; Cavanagh 1991; Cavanagh and Mather 1989), which have in turn led to rebuttals (eg Petersik 1991, 1994). However, the two-process distinction has never been rigorously formulated as a testable theory. Rather, it has been an a posteriori explanation that has been added to, reformulated, and modified over time (see Petersik and Rice 2006). In any case, it has never been a simple, single-factor type of explanation in which a percept is determined by the value of a single stimulus dimension (eg ISI).

At its most fundamental level, the two-process distinction postulates the existence of a long-range process (LRP) which is said to produce apparent-motion percepts over relatively long spatial ranges and relatively long temporal durations, along with

a short-range process (SRP) which is said to produce apparent-motion percepts over relatively small spatial scales and relatively short temporal durations. Further, the LRP has often been thought to reflect the operation of 'higher-order' perceptual processes, whereas the SRP has been thought to reflect the activity of 'lower-order' processes. The two AM processes are sometimes said to be in competition, with only one of them dominating consciousness at any moment. Petersik (1989) recognized the multifactorial nature of the operation of these hypothetical processes and hence argued that the exact spatial and temporal parameters associated with the LRP and SRP depend upon other stimulus values such as luminance, contrast, and element size. For example, using the Ternus display Petersik et al (1983) have shown that the spatial displacement limit of the SRP process depends upon the size of the stimulus elements.

Odic and Pratt (2008) reported data from two experiments on the Ternus effect that they interpreted as being incompatible with the two-process 'theory' (their term). In short, using a stimulus that included an occluder appearing during the ISI along with non-identical stimulus-frame durations (in contradistinction to the typical Ternus display), the authors were able to obtain element movement across a wide range of ISIs in a two-element variation of the Ternus display (experiment 1). In experiment 2, they were able to produce a more complex type of AM percept (neither group nor element movement) by varying the placement of an occluder in a three-element variation of the Ternus display. In both cases, the authors claim their data are inconsistent with a two-process 'theory'. Instead, they favor the differential-activation theory of Gilroy et al (2001) which is based on "the differential activation of directionally selective motion detectors" (page 847) in solving the correspondence problem.

The research methods and data of Odic and Pratt are valuable; however, their *interpretation* of the data can be criticized. Therefore, the purpose of the present paper is to show that Odic and Pratt's argument is flawed because of (i) an overly narrow representation of the two-process approach; (ii) use of a complex spatio-temporal display that makes interpretation of the data vis-à-vis any theory difficult; (iii) a problematic application of differential-activation theory; and (iv) a misunderstanding of the significance of the dominance of element movement with their display.

2 Narrow representation of the two-process approach

Odic and Pratt make the following claim that they attribute to the two-process 'theory':

> "... Just as element motion should be *impossible* to eliminate at short ISIs because short-range processes *always* signal non-motion of middle elements, it should also be *impossible* to eliminate group motion at high ISIs because the short-range processes have expired and, in their absence, group movement should *always* be perceived." (page 1793, emphases mine)

This understanding of the two-process approach then allows them to reject it when they obtain element-movement percepts with ISIs as long as 120 ms (by their interpretation, outside the temporal range of the SRP). However, there is nothing in Braddick and Adlard's (1978) paper, or in those of later authors, to suggest the impossibility of eliminating motion percepts at any ISIs or, for that matter, mandating the occurrence of motion percepts at any ISIs. The two processes have virtually always been seen as 'in competition', implying that one or the other can dominate at times, depending upon stimulus factors, the most salient perhaps being ISI. Except in the rare case of special stimulus conditions (eg dichoptic viewing of stimulus frames – Pantle and Picciano 1976), the probability of perceiving one movement or the other is generally somewhere *between 0% and 100%*. Petersik (1994) specifically cautioned against arguing that a single stimulus value invariably leads to the dominance of one of the motion processes when the literature, at best, shows that it is characteristically associated with a motion process.

The kind of argument constructed by Odic and Pratt is an example of what Petersik (1994) called the 'criterion approach': the idea that an outcome characteristically "associated with a process *must* be present in order to draw a valid conclusion that the process is operating ..." (page 408, emphasis in the original). The fact that the two-process distinction itself is simple does not imply that the conditions leading to the dominance of one process or the other are simple. Thus, it would seem that the 'theory' that Odic and Pratt refuted is a straw man.

3 A complex display that challenges theoretical interpretation

Most often, the Ternus display is presented such that the basic cycle of stimulus duration and ISI is repeated from three to five times, eg $SD_1 - ISI - SD_2 - ISI - SD_1 \ldots$. As stated above, the SDs are typically equal, in the neighborhood of 100 – 400 ms. The ISI is often an experimental variable ranging from 0 to about 100 ms. The study of Odic and Pratt is an exception in that SD_1 was 500 ms, while SD_2 was 2000 ms in experiment 1 and 800 ms in experiment 2. Additionally, a trial consisted of only one presentation of each stimulus frame and one ISI. Experience with the Ternus display in my laboratory suggests that one's initial motion impression (eg after a single SD – ISI cycle) may not be stable. That is, it may require more than one cycle of the stimulus frames for a percept to fully dominate. While it is quite likely that both SRP and LRP can be favored by unusual SDs, ISIs, and luminances, there are no parametric investigations to inform readers what should be expected in such cases. Certainly it wouldn't be appropriate to make predictions solely on the basis of ISI alone in a situation where there is a complex spatial and temporal sequence of stimuli.

Other aspects of the Odic and Pratt study lead to questions regarding how well one could apply the two-process 'theory'. The occluder used in experiment 1 was a gray rectangle (on a black background) that covered the area previously occupied by the two gray stimulus dots (also on a black background). The occluder occurred during the nominal ISI period; however, for at least two reasons one can question whether the ISI was in fact 'inter-stimulus'. First, and most importantly, the occluding rectangle was a stimulus in its own right. Since it had the same contrast polarity and overlapped the same positions as the stimulus dots of the previous frame, it is easy to see that it could signal 'non-movement' in the classical SRP sense. That is, the occluder was yet another spatial stimulus overlapping the position of a previous stimulus, and thus for this display a stimulus appeared without interruption in the same spatial location across three frames rather than just two. The failure to see group movement in this case would be no more surprising than if the dots had simply appeared (or rather, never disappeared) during the nominal ISI period, in which case gray dots would be visible on all three frames, one of which would be in the 'overlapping' position signaling non-movement. Thus, the ISI frame in this study is, in some sense, a third stimulus frame. In any case, in the displays of Odic and Pratt the nominal ISI frame is certainly not a typical 'between-stimuli' blank frame.

Further, in order to present a like-polarity occluder during the nominal ISI, the background of the ISI frame had to have the same luminance as the stimulus frames. This is also not characteristic of many versions of the Ternus display which, instead, often have stimulus frames with a polarity opposite to the backgrounds of the ISI frames.[(1)] In short, these points demonstrate that, despite its similarity, the display of Odic and Pratt was not a typical Ternus display.

[(1)] In fact, using black stimulus elements on white backgrounds, Petersik and Pantle (1979) showed that increasing the similarity of the background luminances between stimulus and ISI frames strongly biased the percepts to group movement. Thus, a maximally bistable black – white Ternus display tends to have a dark ISI.

4 Problematic application of differential-activation theory

Critical to the Odic and Pratt's use of differential-activation to explain the Ternus effect is their notion of temporal summation of contrast (TSC). They state:

> "...for the spatial location of each element there is a temporal summation of luminance differences across the three frames; this difference is pronounced by the contrast of luminance between the background and the element itself." (page 1795)

The authors go on to state that, when TSC is high for a given position, the element is seen to move, whereas, when TSC is low, the element remains stationary (in a sense, mimicking similar kinds of statements made with regard to the role of ISI in the two-process approach). Thus, when TSC is high for all elements, group movement should be seen and when TSC is low for the 'overlapping' elements, element movement should be seen. However, existing data suggest that the relationship between the movement sensations and contrast is more complex (Petersik and Pantle 1979). Petersik and Pantle varied stimulus contrast in two experiments, also examining the temporal integration of contrast. In experiment 3 contrast was varied by manipulating the luminance of the ISI frame; in experiment 4, by varying the luminance of stimulus dots relative to their background. Petersik and Pantle write: "...the range of absolute stimulus contrasts over which reduction in stimulus contrast affected the percentage of group movement responses in experiment 4 does not coincide with the range of effective stimulus contrasts over which reductions affected the percentage of group movement responses in experiment 3" (page 149). Later, they conclude "some process other than temporal integration and reduction of effective stimulus contrast must be responsible for the effects of ISI illumination in experiment 3" (pages 149 – 150).

Apparently unaware of the above contradiction, Odic and Pratt continue:

> "...at short ISIs, the brevity of the second frame prevents the TSC from being high enough to activate the motion detectors for the overlapping elements, and they are perceived as remaining stationary. ...At longer ISIs, the contrast summation is high for all elements, which are subsequently seen to move to their nearest neighbors, thus producing group movement." (page 1795)

This leaves an unanswered need for further clarifications: while ISI is apparently important, it is not clear what the authors regard to be the dependence of TSC upon ISI. Even short ISIs are frequently perceptible to an observer of the Ternus display. Then, why don't they appear to lead to high TSC? In any case, even if one accepts this account on face value, it is clear that it implies that a shift of some kind occurs at some critical ISI. Whether one calls this shift a failure to activate movement detectors, or the activation of a non-movement-signaling SRP, seems like a purely theoretical difference, since neural processes have not been directly examined. In both cases there is a changeover from one type of processing to another. Similarly, the difference between a grouping process and a process that pairs non-stationary elements with nearest neighbors seems almost semantic.

However, a more critical issue arises when considering the measurement of TSC. From what was reported (and which appears above), it is not clear how this summation takes place. Is TSC thought to be a sliding average or a summation over a brief temporal window? If the latter, is there a stimulus factor that determines the duration of the window? What exactly are the roles of temporal transients? How are spatial parameters incorporated (eg, does the area of the stimulus element and/or occluder make a difference independent of changes in luminance; cf Casco 1991)? Over what area(s) is TSC measured in a multi-element display? Is contrast assumed to sum linearly, either in space or in time? In the absence of further empirical or theoretical clarification, it is difficult to come up with even hypothetical numbers to demonstrate TSC

differences between short- and long-ISI conditions without making potentially biasing assumptions.

The above notwithstanding, even if one accepts TSC on a qualitative explanatory level, it still runs into trouble (as hinted by Odic and Pratt, page 1803): Kramer and Rudd (1999) and Petersik and Rice (2008) have both shown that Ternus displays having the same contrast and ISI (and therefore the same TSC) can be biased to produce a majority of either group- or element-movement responses, depending on how identity-related factors like texture are presented. This returns the debate back to the notion that the alternative percepts obtained with the Ternus display are determined by complex interactions among stimulus factors.

5 Significance of the dominance of element movement

In view of the importance of contrast relations in Odic and Pratt's application of differential-activation theory to the Ternus display, an investigation that parametrically varies the luminance of stimulus elements and backgrounds in the Odic and Pratt variation of the Ternus display would be helpful.

In any case, Odic and Pratt appear to place some significance on the fact that their display eliminated group movement, whereas "there have been several studies examining the elimination of the element motion" (page 1792). It is worth recalling the statement above that actual 'elimination' in fact vary rarely occurs. Rather, there is often a shift in the percentage of reports of group and element movement over stimulus conditions. Such shifts are, in fact, consistent with the notion that the two processes of the two-process distinction are in competition. Nonetheless, there is no novelty in showing that element movement can be favored over group movement (see, eg, Petersik 1989, 1994). For example, Casco (1991) had observed element motion at ISIs longer than those used by Odic and Pratt—in her case up to about 230 ms. This was achieved by varying the sizes of the overlapping elements relative to the sizes of the outer elements. Since the relative sizes of elements, rather than luminance or contrast, appears to be the critical variable in the case of Casco's data, it is not at all clear how her results could be explained by TSC/differential-activation. While Casco herself argued in favor of a single-process theory, Petersik (1994) suggested that her data provided evidence for variability in the balance between two motion processes. Thus, it was not necessary to reject a two-process type of explanation.

Dawson et al (1994) varied the polarity of Ternus elements both within and between stimulus frames and discovered that some polarity patterns strongly biased observer percepts toward element movement. Further, Scott-Samuel and Hess (2001) varied a luminance grating that appeared within the Ternus element such that its phase (with respect to the so-called 'overlapping' elements) either coincided across frames or was phase-shifted across frames. They found that elements with the same phase across frames favored the element-movement percept. Neither group of authors favored the two-process distinction when interpreting their data. However, the fact remains in both cases that under certain conditions group movement prevailed while under other conditions element movement prevailed. In terms of the two-process distinction this simply implies that certain stimulus conditions favor the SRP while other conditions favor the LRP.

6 Conclusion

The interpretation Odic and Pratt gave to their data can be questioned on several grounds. In particular, I disagree with their suggestion that a two-process distinction is not compatible with their results. This distinction remains a useful heuristic for understanding data in a variety of AM studies and could at some future time evolve into a rigorous theory.

References

Bischof W F, Lollo V di, 1990 "Perception of direction-sampled motion in relation to displacement and spatial frequency: Evidence for a unitary motion system" *Vision Research* **30** 1341 – 1362

Braddick O J, Adlard A, 1978 "Apparent motion and the motion detector", in *Visual Psychophysics and Psychology* Eds J C Armington, J Krauskopf, B R Wooten (New York: Academic Press) pp 417 – 426

Casco C, 1991 "The relationship between visible persistence and event perception in bistable motion display" *Perception* **19** 437 – 445

Cavanagh P, 1991 "Short-range vs long-range motion: Not a valid distinction" *Spatial Vision* **31** 2109 – 2148

Cavanagh P, Mather G, 1989 "Motion: The long and short of it" *Spatial Vision* **4** 103 – 129

Dawson M R W, Nevin-Meadows N, Wright R D, 1994 "Polarity matching in the Ternus configuration" *Vision Research* **34** 3347 – 3359

Gilroy L A, Hock H S, Ploeger A, 2001 "Differential activation solution to the motion correspondence problem" *Perception & Psychophysics* **63** 847 – 861

Kramer P, Rudd M, 1999 "Visible persistence and form correspondence in Ternus apparent motion" *Perception & Psychophysics* **61** 952 – 962

Odic D, Pratt J, 2008 "Solving the correspondence problem within the Ternus display: The differential-activation theory" *Perception* **37** 1790 – 1804

Pantle A J, Picciano L, 1976 "A multistable movement display: Evidence for two separate motion systems in human vision" *Science* **193** 500 – 502

Petersik J T, 1989 "The two-process distinction in apparent motion" *Psychological Bulletin* **106** 107 – 127

Petersik J T, 1991 "Comments on Cavanagh and Mather (1989): Coming up short (and long)" *Spatial Vision* **5** 291 – 301

Petersik J T, 1994 "Conceptualizations of short-range and long-range processes in apparent movement" *Theory & Psychology* **4** 405 – 431

Petersik J T, Pantle A J, 1979 "Factors controlling the competing sensations produced by a bistable stroboscopic motion display" *Vision Research* **19** 143 – 154

Petersik J T, Pufahl R, Krasnoff E, 1983 "Failure to find an absolute retinal limit of a putative short-range process in apparent motion" *Vision Research* **23** 1663 – 1670

Petersik J T, Rice C M, 2006 "The evolution of explanations of a perceptual phenomenon: A case history using the Ternus effect" *Perception* **35** 807 – 821

Petersik J T, Rice C M, 2008 "Spatial correspondence and relation correspondence: Grouping factors that influence perception of the Ternus display" *Perception* **37** 725 – 739

Scott-Samuel N E, Hess R F, 2001 "What does the Ternus display tell us about motion processing in human vision?" *Perception* **30** 1179 – 1188

Ternus J, 1926/1938 "The problem of phenomenal identity"; English translation in *A Source Book of Gestalt Psychology* Ed. W D Ellis (1938, London: Routledge & Kegan Paul)

Ullman S, 1979 *The Interpretation of Visual Motion* (Cambridge, MA: MIT Press)

ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION
VOLUME 39 2010

www.perceptionweb.com