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Mini review

Phi is not beta, and why Wertheimer's discovery launched the Gestalt revolution

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Abstract

Max Wertheimer (1880–1943), the founder of the Gestalt School of Psychology, published a monograph on the perception of apparent motion in 1912, which initiated a new direction for a great deal of subsequent perceptual theory and research. Wertheimer's research was inspired by a serendipitous observation of a pure apparent movement, which he called the φ-phenomenon to distinguish it from optimal apparent movement (β), which resembles real movement. Wertheimer called his novel observation 'pure' because it was perceived in the absence of any object being seen to change its position in space. The φ-phenomenon, as well as the best conditions for seeing it, were not described clearly in this monograph, leading to considerable subsequent confusion about its appearance and occurrence. We review the history leading to the discovery of the φ-phenomenon, and then describe: (i) a likely source for the confusion evident in most contemporary research on the φ-phenomenon; (ii) the best conditions for seeing the φ-phenomenon; (iii) new conditions that provide a particularly vivid φ-phenomenon; and (iv) two lines of thought that may provide explanations of the φ-phenomenon and also distinguish φ from β. © 2000 Elsevier Science Ltd. All rights reserved.

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1. The question motivating this review

Gestalt Psychology, which played such an important role in the study of perception throughout the first half of the 20th century, was launched by Wertheimer's (1912) publication on 'apparent movement' (Ash, 1998). Apparent movement is said to be perceived when no stimulus actually moves (changes position over time) in the visual field. Apparent movement is called an 'illusion' because this perception of motion is not 'veridical', i.e. the percept does not agree with conditions present in the physical world.

How could a paper on apparent movement published in 1912 create a sufficient stir to launch what has been called a revolution in perception? This question created quite a hullabaloo, when it was raised too forcefully to be ignored by a communication major in one of our perception classes almost 20 years ago. Why was this student, and others once it came up, skeptical about Wertheimer's publication launching a revolution in perception? These students simply did not understand how a study of apparent movement could be newsworthy in 1912 because they knew that watching 'movies' (a term that also entered our language in 1912) had been commonplace since 1900. Several members of the class had even heard of 'nickelodeons', i.e. movie theaters charging 5 cents to see early cinema classics such as the 'Great Train Robbery'.

These students obviously had a valid point. This encouraged one of us (RMS) to look into research on apparent motion prior to 1912, where it soon became

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clear that Wertheimer would need a very unusual observation, indeed, to create the stir he did because a great deal was known about apparent motion before he published in 1912. The interested reader should consult Boorstin's (1992) lucid treatment of the development of the cinema from a report Peter Mark Roget (of Thesaurus fame) made to the Royal Society of London in 1824. His report, confirmed by Sir John Herschel, led to the development of many toys based on the principle of animation, i.e. the rapid viewing a sequence of suitable drawings. By 1877, Muybridge (1955, 1957) had animated a sequence of photographs of a galloping horse that won a bet for Leland Stanford. In 1888, 'Fred Ott's Sneeze' was the first film photographed on celluloid in Edison's laboratory. This encouraged Edison to purchase Armat's *Vitascope*, the first successful projector, which he advertised as 'Thomas A. Edison's latest marvel'. So by 1912 (the year Wertheimer published) Edison could boast that:

> I am spending more than my income getting up a set of 6000 films to teach the 19 million students in the schools of the United States to do away entirely with books.
>
> In Europe, inventors were improving the apparatus for an audience dazzled by the mere spectacle of pictures in motion … George Miliès (1861–1938) …made more than four hundred films [by 1910], which exploited the camera with stop motion, slow motion, fade-out, and double exposure to show people being cut in two, turning into animals, or disappearing … By the opening of the twentieth century, the basic technology of the silent films had been developed, but the art was yet to be created (pp. 740–741).

Clearly, the students were justified in being concerned about Wertheimer's initiation of the Gestalt revolution by publishing a paper on apparent movement when he did. Apparent movement was already known. It had been used in practical applications for more than 60 years, and many of its properties seemed to have been worked out before Wertheimer published. This concern motivated our search for Wertheimer's innovation, the real source of the Gestalt revolution. There had to be more to it than was contained in textbooks used in contemporary introductory psychology and perception courses. We examined 11 introductory and seven perception texts published since 1990. They were not much help. Most treated Gestalt psychology as an important development in the study of perception, a few mentioned Wertheimer's 1912 paper and named his novel observation, the φ-phenomenon, but not one provided a description sufficient to explain how the φ-phenomenon could start a revolution in perception[1].

This encouraged us to look for the answer ourselves. What did Wertheimer observe that was genuinely novel? We began our search by consulting Boring's description of Wertheimer's work in Sensation and Perception in the History of Experimental Psychology (1942)[2]. We believe that an error in the following paragraph about where in the switching cycle the φ-phenomenon was to be found that misled many readers of Boring's (1942) influential book. Clarifying material has been added [in brackets] to make this passage easier to follow. This paragraph leads the reader to expect to

[1] Two interpretations of what Wertheimer meant when he used the label 'phi' can be found in the literature on apparent movement. The first interpretation of 'phi' has it refer to 'pure' movement in the sense that the movement is perceived in the absence of any object seen to be changing position in space. The second interpretation of this label has it refer to 'phenomenal', a term used by philosophers called, 'phenomenologists', who use it to refer to an unanalyzable mental state. Sigmund Exner (1888), the neurologist Wertheimer studied with while at the Charles University in Prague in 1898, held that the perception of movement was phenomenal in this sense of the word. Movement did not have to be inferred from the analysis of sensations produced by objects changing position in space. In this review, we will confine our use of the label 'phi' to refer to 'pure' as defined above. The distinctions inherent in the term 'phenomenal' are too subtle and philosophical to be relevant to the points at issue in this review.

[2] One might wonder why we simply did not turn to the source paper, Wertheimer (1912). The answer is simple. None of the authors were fluent in German. We did consult two German experts after discovering that Boring had gotten it wrong. They could not help probably because neither was expert in perception nor steeped in the jargon used by German psychologists 80 years ago. We were not the first to run into difficulties with the source paper.

Kolers (1972) in his monograph, *Aspects of motion perception*, says:

> "The paper (Wertheimer, 1912) had an enormous impact on experimental psychologists both because of the phenomena discussed and because of its special phenomenological approach to experimentation. Regrettably, the paper is not available in complete translation and in any case is sometimes difficult to read. As Shipley (1961) remarked about his own very useful abstract: This paper is particularly difficult to translate because of Wertheimer's deliberate use of words and phrases in a novel manner, i.e. as symbols of the event (e.g. 'Stationary-position-character') rather than as simple names or descriptions. In other words, Wertheimer's phenomenological approach to perception was expressed in his highly nominalized descriptions as well (p. 13)".

It is also worth noting that Wertheimer provided not one single clear description of the φ-phenomenon in his 104 page monograph. Most of this monograph is devoted to examples of other kinds of apparent movements, particularly to partial movements and to descriptions of experiments designed to rule out a role for eye movements in apparent motion. A detailed analysis of this difficult monograph can be found in Sekuler (1996).

see. near the slowly switching end of the temporal continuum. It is actually at the other end. Simply put, Boring listed the φ-phenomenon in the wrong place in the switching sequence.

> Wertheimer simplified the observational situation. Instead of continuously occurring discrete displacements of the stroboscope or kinetoscope, he arranged, with a tachistoscope, for a single discrete displacement of a simple geometric figure, a line or a curve. The first member he designated ***a*** the second member ***b***. When the time interval between ***a*** and ***b*** was relatively long (above 200 ms) the subject perceived succession, first ***a***, then ***b***. When the interval was very short (less than 30 ms), the perception was one of simultaneity, ***a*** and ***b*** together. In between successivity and simultaneity, he got movement, the optimal interval for which was about 60 ms. For times within the movement — optimum and successivity [i.e. when switching was slowed down from where a single object appeared to move from one place to another until the subject saw ***a*** followed by ***b***, rather than a single moving object] the subject perceived various kinds of partial movement. For instance, as the time-interval is increased above the optimum [i.e. the switching of ***a*** and ***b*** is slowed down, moving the percept towards successivity], the seen movement tends to break up into a dual movement in which each part moves with a lack of continuity, or into a singular movement in which one part moves and the other is stationary. In these cases, instead of seeing a single object move, the subject sees two successive objects with one or both of them moving. Within this interval there is also the case of pure movement named φ, movement which connects the objects and has direction between them but seems not in itself to be an object. The series for increasing time-intervals [i.e. from faster to slower alternations] is therefore something like this: simultaneity — optimal movement — partial movement — pure movement (φ) — succession. …φ-movement (Wertheimer, 1912) is pure movement that is seen without a moving object and the basis for the claim that movement is as primary as any other sensory phenomenon. (p. 595).

Boring's definitions of φ and optimal movement (β) are fine. His description of Wertheimer's observations are also. He got only one thing wrong. Namely, the φ-phenomenon is observed near simultaneity not near successivity, i.e. near where alternation is fast and both ***a*** and ***b*** are visible simultaneously. The φ-phenomenon is not observed when the switching speed is increased from successivity towards optimal-movement (β). This, rather mysterious, error in Boring's influential book probably led to the confusion about Wertheimer's revolutionary phenomenon that is evident in most contemporary textbooks.[3] One will not see φ if one looks for it where Boring suggested.

How did we discover Boring's error? We discovered it when we tried to set up a demonstration that would convince our students that φ was really a special kind of perceived movement; φ was a kind of movement they had never seen before, not in the movies, not on marquees, and not even on TV. We thought that this would be easy to do because legend had it that Wertheimer made his novel observation while playing with a child's toy on a train during the summer of 1910. We did not, therefore, anticipate needing any fancy, high tech equipment to demonstrate φ. In Boring's (1929, 1957) version of this legend, φ was observed with a 'toy stroboscope'. One of us (RMS) had heard Hans Wallach's (1954) version, which differed significantly. Wallach said that Wertheimer observed φ, while flipping through a stick-figure picture book he was bringing to the child of a friend he was going to visit. Fortunately, only Wallach's version was remembered when our search for φ began because it encouraged us to use continuous, rather than discrete stimulation. We could have easily overlooked the φ-phenomenon had we started looking for it with discrete pairs of flashes separated in time. Wertheimer's novel phenomenon, φ, is probably impossible to see when it is produced by single pairs of flashes, but quite easy to see when appropriate stimuli are presented repeatedly.

We started our search with a square-wave generator, an XY oscilloscope display and a defocused spot. The spot, which looked like a bright disk in an otherwise dark room, was stepped back and forth at various frequencies. Frequency was varied until we saw something that matched our expectations about what φ should look like, specifically, a region moving all by itself. No objects, whatsoever, should be seen to be moving when φ is seen. When we switched slowly, we saw the expected successive alternation of a single disk (successivity). When switched rapidly, we saw the expected simultaneous pair of disks (simultaneity). All

[3] Contemporary texts do not always neglect the distinction between φ and β nor misplace the φ-phenomenon in the switching sequence as Boring (1942) did. Palmer (1999) got its position just below simultaneity correct, but his description, 'phi motion … is perceived between the two lights without the perception of intermediate positions', is less than completely satisfying (p. 472). Kai von Fieandt (1966) also got the order right, but described the φ-phenomenon in a more satisfying way, namely:

> Wertheimer 'in his most crucial study (1912) presented successive views of two short vertical lines… [and] observed a peculiar phenomenal motion, never clearly described before if the blank interval was brief enough… both straight lines were seen simultaneously; nevertheless, something was perceived as moving from A to B. This was not a stroboscopic motion proper, because line A was not seen to move over to B. Rather it was an objectless movement, or 'pure motion' as Wertheimer called it. Without seeing any moving objects or figures, there was a clear impression of motion from one place to another' (p. 263).

of the other expected phenomena were also seen easily, including optimal movement (β), partial movements and φ. But, φ clearly was not where Boring claimed it should be. It was at the high end of the switching frequency range, not at the low end. The φ-phenomenon is seen when the spots producing it are stationary but flickering. The pure movement is perceived as moving in counterphase to the flicker of the stationary disks producing it. Flicker seems to be a necessary condition for seeing φ, at least when φ is produced by the alternation of only two or three bright objects viewed in a darkened room.

The φ-phenomenon, observed under the conditions described above, is relatively easy to see. When generated by bright stimuli on a dark background, φ appears as a moving dark black, or, some say, a dark purple, flag-like region, that flaps back and forth between, and slightly around, the stationary pair of slightly flickering disks producing it. Its shape is ambiguous. It does not look like an object, so observers, as one might expect, describe its appearance with difficulty, but consensus about the percept of something dark moving in the region between, and often a bit around, the slightly flickering disks is readily achieved. If φ is viewed with dark stimuli on a bright background, the flapping flag is reported as light or bright or silver. Some observers say it is less prominent than the dark 'flag' produced by bright disks on a dark background. Others report the bright flag as more prominent, but some find the bright and dark versions of φ equally compelling. Consensus about the existence of a percept of a pure movement can be achieved despite variability in descriptions of its shape and its prominence under the white/black and black/white stimulating conditions. It is worth noting that φ changes direction too fast to be smoothly pursued (Martins, Kowler & Palmer, 1985), and that switching rates high enough to produce φ are too fast to be tracked with saccades. The fact that eye movements have nothing to do with φ, or with any other apparent movement with the possible exception of autokinesis, was made clear by Wertheimer in his original paper. This possibility, however, has been raised a number of times since (see Kolers, 1972, for some attempts to relate the perception of apparent movement to eye movements).

2. Our answer was accepted by the students

Once the appearance and stimulating conditions required for demonstrating the φ-phenomenon were known, it was a simple matter to convince our students that Wertheimer had made a novel, as well as compelling, observation. The φ-phenomenon was newsworthy, indeed. Our professorial credibility was restored. Our simple demonstration has been effective in both small (40) and large (120) classes. Students simply stand in a group as far as possible from the display along with the teacher, who adjusts the dial on the signal generator until s/he experiences all of the relevant phenomena. Only minor adjustments of the square-wave frequency are required to ensure that everyone in the class experiences all of the phenomena. Explaining exactly what one expects to see under each of the stimulating conditions helps considerably. Establishing a 'set' helps naive observers see both φ and β. Analytic studies, however, of apparent movement are best done with discrete tests, unpredictable spatial-temporal relationships and variable interstimulus intervals. But, this is not the way to study the φ-phenomenon, or to produce convincing demonstrations of φ for groups of naive, undergraduate students. It is, however, a good way of collecting data that allows the experimenter to doubt the existence of the φ-phenomenon. See Dimmick (1920) and Higginson (1926) for examples of research done with this in mind. Also, see Neff's (1936) review and Kolers (1972) monograph for discussions of these and other authors' work on apparent movement, including φ and β.

When we did a final literature search while writing this review, we discovered Sekuler's (1996) thoughtful treatment of Wertheimer's many contributions to motion perception. His and our treatments overlap considerably, but our purpose, emphasis and conclusions are quite different. We set out to rediscover the φ-phenomenon, which Wertheimer distinguished from optimal movement (β), the kind of apparent movement that was well known when Wertheimer published his seminal paper in 1912. We also wanted to understand why φ, but not β, had been controversial in its day, and why there has been confusion about this distinction ever since. Sekuler's (1996) stated purpose was quite different. He set out:

> to clarify what [Wertheimer's] monograph did and did not contribute, emphasizing links between Wertheimer's principal findings and the results of subsequent investigations of motion perception, including currently active lines of research ... The topics discussed include ... his work on motion phenomena that lie between succession and optimum motion (p. 1243).

Our review concentrates on the other end of the switching range, the region between optimal motion (β) and simultaneity because it is here that the φ-phenomenon is actually found. Sekuler's review mentions φ only briefly, where he includes a quote from Wertheimer's paper which states that it is 'objectless motion'.

We believe that we have been successful with respect to our goal. We have rediscovered Wertheimer's original phenomenon, and now understand how it might have served to launch what has been called the Gestalt revolution. Our next step was to make our work available to those, like us, who teach perception from an historical perspective. One of us (FJP) did this by developing a

JAVA Applet for use in classroom demonstrations. This Applet, which has been tested successfully in both large and small classrooms can be viewed at: http://psych.purdue.edu/magniphi/. Readers should feel free to download this demonstration and to use it for their teaching.

3. Now that we know: (i) what φ is; (ii) where to find a demonstration, allowing one to see it, we can ask: (iii) how can the φ-phenomenon be explained; and (iv) can the explanation distinguish φ from β?

Wertheimer's explanation was as novel as the φ-phenomenon, itself. He proposed that short-circuits between circles of excitation in the cerebral cortex produced by discrete stimulations varying in time and space provided the physiological underpinnings for *all* apparent movements perceived. He even claimed that the neural correlates of the perception of real movement were the same. Both ideas were implausible in their day and ever since. We also know of no attempt he, or his colleagues or students, made to distinguish φ from β (see Kolers, 1972, for now traditional criticisms of Wertheimer's explanation, and also for a sympathetic treatment of the contributions that did result from Wertheimer's studies of apparent movement).

More recently, a number of authors have taken up the question of the basis of the apparent movement illusions and their relationship to the perception of real movement (e.g. Braddick, 1974; Anstis, 1978; Cavanagh & Mather, 1989; Lu & Sperling, 1995; Francis & Grossberg, 1996). The emerging view seems to be that there are two or perhaps even more distinctive mechanisms for processing apparent and real movement, each mechanism operating for a different type of a stimulus (apparent versus real movement, small versus large displacements, the presence versus absence of higher order features). None of these studies presented a theory of φ, as distinct from β, probably simply because of the confusion described earlier. Proposing a theory of φ that can also explain β at both the perceptual and neurophysiological levels of analysis is beyond the scope of this paper. We will, however, present two lines of reasoning that might lead to the development of such a theory.

The first line of reasoning applies at the neuroanatomical level. Starting with Ungerleider and Mishkin's (1982) study, a number of investigators conjectured that visual information is processed in two separate anatomical pathways originating at V1. One pathway, which processes position and motion, goes to the parietal cortex. The other pathway, which processes form and color, goes to temporal cortex. Whenever an object is moving or changing position, it is likely to stimulate both pathways and the result is the percept of real or illusory (β) movement. If, however, the change of the position of the object is too rapid (e.g. the frequency of flickering is too high), it may stimulate only the motion pathway because the motion pathway does process high speeds (Newsome, Mikami & Wurtz, 1986), but the form pathway does not (Levitt, Kiper & Movshon, 1994). As a result, the percept may be of a pure movement, i.e. a movement without any form (the φ-phenomenon). It is an open question at this time whether this line of reasoning would lead to a completely new mechanism, unrelated to the mechanisms responsible for other types of illusory movements. It is also not clear that this line of reasoning would be able to account for at least one other characteristic of the φ-phenomenon that we call 'colored φ'. Colored φ refers to the observation that the pure movement *always* has the color of the background. If the inducing disks are white and the background black, φ is black. If the disks are black and the background white, φ is white. This seems to be true of all combinations of colored disks and backgrounds. (An option to vary disk and background colors is included in the Applet to permit the reader to check this out. This option was made available for the stimulating condition in which φ is most vivid and its relationship to the background most apparent.)

The second line of reasoning applies at the cognitive level. It is based on the assumption that the visual system solves an inverse problem of perceptual interpretation (Poggio, Torre & Koch, 1985).[4] Specifically, given the proximal stimulus produced by an object (its representation at the retina where its image is transduced), the task for the visual system is to infer the object itself. Since the proximal stimulus does not provide complete information about the physical world, there is always more than one possible interpretation. To obtain a unique, and possibly veridical interpretation, the visual system has to impose constraints on the set of possible interpretations. These constraints often take the form of a simplicity (Prägnanz) or likelihood principle. This line of reasoning has already been applied to a number of visual phenomena. Only two of the most relevant cases will be described here.

First, consider a stationary phenomenon known as 'illusory contours' (Kanizsa, 1974). If a set of bright lines on a black background is 'occluded' by a black figure with regular contours, one can easily see the black occluding figure even though the contours of this figure are physically absent. Clearly, the visual system performs interpolation between the endpoints of the bright lines. A possible explanation invokes the likelihood principle

[4] We want to emphasize that by invoking a 'cognitive' explanation we are not proposing that perception involves thinking in the same way as it is involved in playing chess. It is a cognitive explanation in the sense that a relatively high level of inference, based on such principles as simplicity or parsimony, is used by the visual system when it solves the problem of interpretation. These inferences are made by applying a set of innate (hard-wired) rules of perceptual organization.

(constraint) mentioned above. Namely, it is more likely that the non-accidental arrangement of the endpoints of the bright lines was produced by an occluding figure (object) than by pure coincidence (Gregory, 1980). One can also say that the interpretation by means of an occluding figure is more parsimonious (Chater, 1996). In both cases, the visual system uses figure–ground segregation to solve the problem of visual interpretation.

Next, consider the apparent movement of an illusory figure in the presence of flickering lights that was used by Sigman and Rock (1974). Their stimulus was a pair of flickering lights and a pair of flickering illusory figures. The positions of the lights and illusory figures were identical, but the illusory figures were larger than the lights. The flicker of the lights and the illusory figures was synchronized: When the left light was on, the illusory figure was shown on the right. When the right light was on, the illusory figure was shown on the left. This stimulus allows for at least two different interpretations. First is the apparent movement of the light and the apparent movement of the illusory figure. The second interpretation is the apparent movement of the illusory figure in front of two stationary lights (note that figure–ground segregation is involved here also). The percept corresponds to the second interpretation. This can be explained as follows: Once the apparent movement of the illusory figure is perceived, this movement 'accounts for' the flicker of the lights, and the apparent movement of the light need not be invoked. Clearly, the movement of the occluding illusory figure in front of two stationary lights is a more parsimonious (or more likely) visual interpretation than the synchronized movement of both the occluding illusory figure and the light.

Sigman and Rock's (1974) demonstration brings us to the φ-phenomenon. One can think of the φ-phenomenon as an occluding illusory movement. It is a pure (objectless) movement in the sense that there is nothing in the stimulus that specifies the shape of the occluding object. The φ-movement, itself, 'accounts for' the flicker of the lights. As a result, the observer perceives two stationary lights with pure movement occluding them. Here, figure–ground segregation is involved again, except that no figure is perceived! Pure movement is perceived in lieu of a figure. Note that this kind of explanation can be applied to the case of colored φ (described above). Specifically, it predicts that φ must take on the color of the background, regardless of the color of the flickering lights because φ, itself, is not an object. We believe that we are the first to make this claim, specifically, φ will always have the color of the background because the conditions responsible for it cannot produce conventional figure–ground segregation. This is precisely what the observer perceives. The contourless, pure movement, called φ, always has the color of the background. Furthermore, if this explanation is adequate, it should be possible to design other stimuli, based on the same principle, that would lead to a particularly vivid φ-phenomenon. We have done this and came up with a very vivid illusory pure movement percept we like to call, 'magni-phi'[5] (see the Applet).

This demonstration uses a set of n disks ($2 \leq n \leq 17$). The fact that the demonstration is much richer than a display with only a pair or three disks leads to the expectation that φ, the pure movement, perceived would be both more stable and more vivid than any φ seen before. The disks in the Applet, flicker in such a way that the 'off-disk' actually travels clockwise, but the observer does not perceive the 'off-disk'. Instead, a pure occluding movement, a dark, contour-less, bar is seen to rotate about the center of the circle. Magni-φ, unlike φ produced by only two or three disks, is not only much more vivid. It is also much more robust to changing parameters such as timing, size, intensity, number of disks, and viewing distance. Magni-φ, unlike Wertheimer's φ, does not require establishing a set to see a pure movement. The contour-less, rotating bar, which always has the background's color, appears without any preparation, whatsoever. It pops out as soon as an appropriate display appears.

4. Addendum following reviews

We discovered that Tyler (1973) and Petersik and McDill (1981) had studied the percept of movement produced by a flickering stimulus and had reported observations of what could be described as 'pure' movement when the manuscript of this paper came back from review. An examination of these papers led to a number of additional prior reports, specifically, Saucer (1953), Zeeman and Roelofs (1953), Saucer (1954), and Allport (1968). Based on their methodology and on the observations reported, we are convinced that all of these authors observed both β and φ movements. None of them, however, used the term 'φ' for the pure movement. Apparently, they were not aware that they had probably independently rediscovered what we believe to be Wertheimer's original observation, the observation that launched the Gestalt revolution. They called the pure movement they observed, 'shadow' or 'omega' movement.

All of these studies, as well as our own observations, show that in the range *between simultaneity and succes*-

[5] The formally correct name for our particularly vivid variety of φ would be 'mega-φ'. 'Magni-φ' mixes Latin and Greek roots. We prefer 'magni-φ', however, and encourage its future use.

sivity, there are only two distinctive percepts, each corresponding to clearly different frequency ranges. The first is an apparent movement that we all call, 'β'. The other is a pure movement that we, and we believe Wertheimer, called, 'φ'. The 'partial' movements reported by Wertheimer and others refer to movements observed in a transitional stage between β and successivity. These partial movements are not a separate, distinct type of apparent movement. β is always described as an apparent movement of a figure (object), whose physical properties (shape, size, color) are identical to the properties of the objectively stationary targets. If the targets generating the apparent movement are different from one another, changes of some or all of these properties are always observed. φ is always observed for frequencies higher than those for β (by a factor of about two), and it is described as a shadow moving between and around the targets. β does not qualify as an objectless, pure movement. Furthermore, β was discovered well before 1912, so it could not have started the Gestalt revolution. Clearly, the only distinctive type of movement (produced by a flickering stimulus), which was not known before 1912, and whose properties fit nicely to what one might call a pure, objectless, movement, is φ, as we describe it in this paper.

The observations described by Petersik and McDill (1981), who studied not only φ, but also studied 'kinetic optical occlusion', might suggest that φ in general, and magni-φ in particular, are only special versions of β. 'Kinetic optical occlusion' refers to the percept of movement produced by sequential erasing of adjacent areas of a textured background by a moving blank form, or the percept of an occluding form produced by erasing parts of a moving background stimulus. In either case, the percept involves both shape and movement, and thus, '*kinetic optical occlusion*' *is not related to φ, because φ does not have shape*. Kinetic optical occlusion seems to be a version of a movement of the sort described by Sigman and Rock (1974).

5. Concluding comment

All academics have occasion to reflect and comment on the way in which research and teaching complement each other. This seems to be particularly appropriate here. Our interest in the φ-phenomenon arose from teaching. Satisfying this 'obligation' led to the development of state-of-the-art application software that allowed us to disambiguate important perceptual phenomena that had been obscured for decades. It is impossible to know at this point how much further the issue raised by an alert student in a perception class will take us, but φ has been fun so far, and magni-φ promises even more.

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