Visual illusions and direct perception: Elaborating on Gibson’s insights

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Gibson argued that illusory pictorial displays contain “inadequate” information (1966, p. 288) but also that a “very special kind of selective attention” (p. 313) can dispel the illusion—suggesting that adequate perceptual information could in fact be potentially available to observers. The present paper describes Gibson’s treatment of geometrical illusions and reviews pertinent empirical evidence. Interestingly, Gibson’s insights have been corroborated by recent findings of inter- and intra-observer variability in susceptibility to visual illusions as a function of culture, learning and task. It is argued that these findings require a modification of the general Gibsonian principle of perception as the detection of specifying information. Withagen and Chemero’s (2009) evolutionary motivated reconceptualization of perception predicts observers’ use of both specifying and non-specifying information and inter- and intra-observer variability therein. Based on this reconceptualization we develop an ecological approach to visual illusions that explains differential illusion effects in terms of the optical variable(s) detected.

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1. Introduction

Geometrical illusions can produce striking alterations of perceived size, shape, orientation or position. In the Müller–Lyer illusion, for example, two equally long lines surrounded by pairs of acute and obtuse angles appear unequal in length, while a ruler reveals that they are not (see Fig. 1a). Indirect perceptionists have often claimed that illusions refute Gibson’s (1966, 1979/1986) theory of direct perception (e.g., Fodor & Pylyshyn, 1981; Gregory, 1997; Rock, 1997; Ullman, 1980). However, Gibson did provide an account of illusions, particularly in the context of his extensive analysis of picture perception (see Gibson, 1966, 1971, 1978, 1979/1986; Goebel, Arneheim, & Gibson, 1971; see also, Gibson, 1970). This paper describes Gibson’s treatment of illusions in detail and reviews pertinent recent empirical evidence. It will be argued that although the evidence is in keeping with Gibson’s treatment of illusions, it does not accord well with the more general Gibsonian conceptualization of perception as the detection of specifying information. Withagen and Chemero (Chemero, 2009; Withagen, 2004; Withagen & Chemero, 2009) have recently developed an evolutionary motivated reconceptualization of information and perception that lets go of a strict specificity principle but maintains the premise of observers’ direct access to optical variables. In contrast
with Gibson, these authors argue that perception typically relies on the detection of both specifying variables and variables that merely correlate with the to-be-perceived property. Moreover, their approach explicitly predicts variability between and within observers in what optical variables are picked up. Based on this work, we develop an ecological approach to visual illusions that explains differential effects of illusions in terms of the optical variable(s) detected by the observer. Our discussion will start with a comparison of indirect approaches to perception and Gibson's theory of direct perception.

2. Direct and indirect approaches to visual perception

Most theories of perception (e.g., Brunswik, 1956; Fodor & Pylyshyn, 1981; Helmholtz, 1878/1971; Knill & Richards, 1996; Koffka, 1935; Neisser, 1967; Purves, Wojtach, & Beau Lotto, 2011; Rock, 1997; Ullman, 1980) assume that the energy patterns impinging on the senses underspecify the environment and therefore cannot form the sole source of information about the environment. The retinal image of objects, for example, varies with the shape and orientation of the object and the observer's distance to it. Thus, one and the same environmental situation can cause different retinal images. Conversely, one retinal image can be caused by more than one environmental situation. Indirect approaches to perception address the problem of ambiguity in the relationship between the stimulus information available from the retina and its cause in the environment by proposing that the visual system actively constructs a meaningful percept of the environment by inferring the environmental cause of the stimulus information. In this process, the impoverished stimulus information that arrives at the senses is enriched with knowledge from biases, expectations, and assumptions based on prior visual experience. Thus, in the indirect view perception is not of the environment itself but of a mental representation of the environment, fabricated by- and residing in the brain. Taking the indirect position to its extreme, Gregory (1998) claimed that we “... carry in our heads predictive hypotheses of the external world of objects and of ourselves. These brain-based hypotheses of perception are our most immediate reality” (p. 1693).

The assertion that perception requires inference runs the risk of having to introduce a homunculus inside the brain—someone or something to infer the cause of the stimulus information—which would lead to an infinite regress; inside the brain of the homunculus another homunculus would be required to attribute meaning to the stimulus information, and so on. Furthermore, perception based on inference seems possible only when one already knows what there is to be perceived, which begs the question of how this knowledge was attained in the first place (Gibson, 1979/1986; Shaw, Turvey, & Mace, 1982; Warren, 2005).

In developing an alternative to the theory of indirect perception that avoids these conceptual problems, Gibson (1950, 1966, 1979/1986) asserted that humans do have direct access to the environment. To this end, he introduced the concept of information as specification, which holds that there is a lawful one-to-one relation between optical variables in the ambient energy array (i.e., the pattern of light that is reflected by the environment) and the properties of the environment or the “organism—environment relation” (see also Turvey, Shaw, Reed, & Mace, 1981). Typically, but not necessarily, optical variables become available as a result of movement of the organism or of the environment. For example, the direction in which a moving observer is heading is specified by the locus of the global expansion pattern in the ambient energy array (Gibson, 1958), and approaching objects bring about local expansion patterns of which the relative rate of change specifies the time-to-contact between the object and the percever (Lee, 1976). As an example of optical variables present in static ambient energy arrays, texture gradients specify the relative size of objects (Gibson, 1966).

Thus, unlike the stimulus information available from the retinal image, optical variables do not relate ambiguously
to the environment; instead, they specify the environment. By actively detecting the information provided by optical variables, humans have direct access to their environment. The process of inference that attributes meaning to impoverished stimulus information, which is central to theories of indirect perception, can thereby be dispensed with. To summarize, for Gibson’s theory of direct perception, given the one-to-one relation between the information provided by optical variables and the environment, all that is required to perceive the environment is the detection of information.\(^1\) By characterizing perception without inference and representation, Gibson dissolved several conceptual problems associated with the indirect approach. However, a new potential problem arose: by defining information as specification, how could Gibson account for instances of illusion?

3. Direct and indirect accounts of visual illusions

Illusions are often presented as evidence par excellence for the indirectness of perception (see Gregory, 1966; Rock, 1997; Ullman, 1980). Take for example Gregory’s (1963) classical explanation of the Müller–Lyer illusion (Fig. 1a), according to which the illusion results from the processing of cues about three-dimensional structure that are claimed to be present in its projections on the retinal images. Specifically, Gregory (1963) argued that the right and left configurations of Fig. 1a represent respectively the inside and outside corners of a building in perspective. In the virtual space of the picture, the inside corner is farther away from the observer than the outside corner. Since the two vertical lines are of identical retinal size, the height of the inside corner is perceived as expanded relative to the height of the outside corner. The Ponzo illusion (Fig. 1b) can be explained in a similar way. In this drawing, two equally long horizontal lines, one placed above the other, are surrounded by converging lines. According to Gregory (1968), the converging lines represent the convergence of a railway with distance. Since the top horizontal line is further away from the perceiver than the bottom line in the virtual space of the picture, but of identical retinal size, the top line is perceived as larger than the bottom line.

Recall that in the indirect approach, perception of the environment results from a process in which stimulus information available from the retina is combined with knowledge from biases, expectations, and assumptions based on prior visual experience. Illusions, then, show that the reliance on prior visual experience in this process is not always appropriate and can sometimes lead to discrepancies between the actual and perceived properties of objects in the environment. Thus, the same inferential process that normally leads to accurate perception can sometimes cause distorted perception of the environment. For this to happen, a situation must be created in which the rules of actual environments (e.g., more distant environmental objects cause smaller images on the retina) are violated. Gregory (1968; see also Gregory, 1980) stated the hypothesis as follows:

But what happens when distance information, such as perspective, is present when there is no actual difference in distance to shrink the image in the eye? Could it be that perspective presented on a flat plane sets the brain’s compensation for the normal shrinking of the images with distance—though in pictures there is no shrinking to compensate? If this happened, illusions must be given by perspective. (p. 288).\(^2\)

Illusions thus conceived seem to provide strong evidence in support of indirect perception and hence against direct perception (Rock, 1997). Indeed, critics of Gibson have often concluded that by arguing that perception is direct, Gibson could not account for the existence of illusions. Gregory (1997), for example, claimed that “[t]o maintain that perception is direct, without need of inference or knowledge, Gibson generally denied the phenomena of illusion” (p. 1122).

However, Gibson did recognize illusions, and commented extensively on them. It is true that from the beginning of his career, Gibson maintained that an account of perception should foremost explain why perception is usually accurate. In his first book, The perception of the visual world, Gibson (1950) stated: “The discrepancies between percepts and objects are not difficult to understand; what we need to understand is why there are so few discrepancies. This is the real mystery and the really important problem” (p. 43). Nevertheless, substantial parts of both Gibson’s (1966; 1979/1986) subsequent books The senses considered as perceptual systems (Chapter 11 and 14) and The ecological approach to visual perception (Chapters 15 and 16) are devoted to the topic of illusions and the related topics of depiction in pictures and film. In addition, Gibson wrote several papers on pictures and the information that is available in them, mainly in the context of his debate with the art historian Gombrich (see e.g., Gibson, 1971, 1978; Gombrich, 1961; Gombrich et al., 1971). Lastly, Gibson, Kennedy, and Toleno (1967, cited in Kennedy & Portal, 1990, p. 49) published empirical work on illusions, examining the stick-in-water illusion in children.

We will start with Gibson’s analysis of picture perception, as this is the context in which he constructed his treatment of illusions. Gibson (1971) distinguished between the act of perceiving a picture and the act of perceiving what is depicted in the picture:

He [the observer] can notice only the information for the perception of what is represented or he can pay attention to the picture as such, to the medium, the technique, the style, the composition, the surface and

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\(^1\) Gibson’s early work was concerned with the direct perception of surfaces (Mace, 2005). He developed the influential affordance concept, which states that the primary objects of perception are an organism’s possibilities for action, when he was already several decades into his career (Gibson, 1966, 1977, 1979/1986). Here, we will focus on the implications of empirical work on illusions for Gibson’s theory on how perception comes about; an appraisal of the implications for his later work on what perception is typically of (affordances), is outside the scope of this paper.

\(^2\) Throughout this paper, emphases in quotations are in the original, unless otherwise stated.
the way the surface has been treated. It is possible of course to shift from one attitude to the other and some pictures fairly compel us to go back and forth from the virtual object that is in the picture to the real object that is the picture. (p. 32).

Thus, when viewing a picture, the observer can detect information that specifies the picture as such and information that specifies the object or situation that is represented in the picture. The crux of Gibson’s analysis of picture perception lies in his notion of information. Crucially, he argues that the information that specifies the virtual object in the picture and the information that specifies the object that is represented in the picture are similar (although not identical, see the two quotations from Gibson, 1971 below). Gibson’s formal definition of a picture reads as follows: “A picture is a surface so treated that a delimited optic array to a point of observation is made available that contains the same kind of information that is found in the ambient optic arrays of an ordinary environment” (Gibson, 1971, p. 31). This conception of pictorial information can account for the perception of a broad range of pictures and the objects, situations and persons that are depicted in them:

This definition covers both the photograph and the caricature. It admits that a photographic color transparency can provide an eye with almost the same brightness and color contrasts that the cone of light intercepted by the camera provided. The relations of luminous intensity and spectral composition of the stimulus energies in the two arrays are in sufficient correspondence to make the low-order stimulus information very nearly the same. But the definition is broad enough also to admit the case of a caricature, where the contrasts of luminous energy are quite different and even the forms are different but where the high-order information to specify a particular person is common to both arrays.

Gibson, 1971, p. 31.

Not mentioned in the above quotation, but also considered by Gibson (1971), are the particular cases of pictures that depict reversible figures (e.g., the goblet-faces display, the Necker cube) and Gestalt figures that can yield two wholly different percepts (e.g., the “duck-rabbit” figure). Regarding these figures, he argued that “the information in the array is equivocal” (p. 33), that is, two incompatible kinds of pictorial information are available and what is seen (e.g., the duck or the rabbit) depends on the particular information that is attended to by the observer.

In addressing geometrical illusions, the types of pictures that are of main interest in the present paper; Gibson (1979/1986) pondered: “Is information always valid and illusion simply a failure to pick it up? Or is the information picked up sometimes impoverished, masked, ambiguous, equivocal, contradictory, even false?” (p. 243). About the Müller–Lyer illusion in particular, Gibson (1966) wrote:

But the information for length of line, I have argued, is not simply length of line. To suppose so is to confuse the picture considered as a surface with the optical information to the eye. A line drawn on paper is not a stimulus. The stimulus information for the length of line is altered by combining it with other lines. We should never have expected equal lengths to appear equal when they are incorporated in different figures. Only if we can isolate the two line segments from the wings and arrowheads in the Müller–Lyer illusion should they appear equal, and this would require a very special kind of selective attention. (p. 313).

This quotation is pertinent in two respects. First, Gibson claimed that the wings and arrowheads attached to the vertical lines alter the information for the length of these lines. Apparently, observers can rely on information that is not specific to the actual length of the line, giving rise to the illusion. Note the sharp contrast between this explanation and that of the indirect approach (e.g., Gregory, 1968, 1997); Gibson accounted for the illusion not in terms of inference but in terms of informational patterns in the ambient array.

Some ecological psychologists (e.g., Kennedy, Green, Nicholls, & Liu, 1992) have termed the optical variables that are contained in illusory pictorial displays “impoverished”. Gibson (1966) also offered an explanation for why the wing and arrowhead configurations of the Müller–Lyer illusion specify different line lengths, proposing, perhaps circuitously influenced by Gregory’s (1963) earlier explanation, that the figure depicts two virtual objects:

Of all the many theories of the Müller-Lyer illusion, the one most nearly consistent with our hypothesis is one of this sort: [the vertical line in combination with the arrowheads (left configuration of Fig. 1a)] contains information for the ridge of a roof seen from above, while [the vertical line in combination with the wings (right configuration of Fig. 1a)] contains information for the ridge of a roof seen from below. The apparent sizes of the two ridge-lines depend on their apparent distances in accordance with the general principle of perception of size-at-a-distance.

Gibson, 1966, p. 313.

Thus, Gibson asserted that the information that is normally used by observers to perceive line length is “inadequate” in the context of the Müller–Lyer illusion (see Gibson, 1966, Chapter 14 for an extensive treatment of his concept of inadequate information). That is, it does not specify length of line in that pictorial display but instead relates ambiguously to it.

The second pertinent point of the earlier quotation, and one that has received particularly scant attention in the literature, is the suggestion that the illusion could potentially be dispelled if observers would direct their attention to the specifying information, that is, if they would “isolate the two line segments” (Gibson, 1966 p. 313) by ignoring the wings and arrowheads. What Gibson apparently anticipated is that an illusory pictorial display can contain two different optical variables, and that the occurrence of the illusion depends on the particular information that is used by the observer; when an optical variable is detected that is not specific to length of line (e.g., “inadequate”, in
4. Variability in susceptibility to visual illusions

There is a long history of interest in cultural differences in susceptibility to illusions. Rivers (1905), for example, reported on the effect of the Müller–Lyer illusion and the Horizontal-Vertical illusion on perceptual responses of peoples in South India, New Guinea and England. South Indians and New Guineans showed less illusion bias for Müller–Lyer displays and a larger bias for Horizontal-Vertical displays than the English. These early findings were confirmed in a now classic study by Segall, Campbell, and Herskovits (1966). They compared members of Western cultures (American and South-African persons of European descent) with individuals in more than 20 non-Western (mostly African) cultures. Again, substantial cultural differences in susceptibility to the Müller–Lyer illusion and the Horizontal-Vertical illusion were found. Segall et al. (1966) argued that more extensive visual exposure to a “carpentered environment”, in which acute and obtuse angles on the retina are normally associated with right angles in the environment, constitute habits of inference to interpret Müller–Lyer configurations as objects with inside and outside corners that extend in space (e.g., following Gibson, 1966; Gregory, 1963). In keeping with this account, it was found that observers from non-Western cultures who were less affected by the illusion lived in environments in which man-made structures with straight lines and right angles were a rarity. A similar hypothesis was offered for the differences in susceptibility to the Horizontal-Vertical illusion; the visual exposure to large open vistas (i.e., plains) would evoke habits to infer frontal-plane horizontal distances from short, vertical retinal images. Accordingly, Segall et al. (1966) showed that plain dwellers exhibited a larger illusion bias than city and forest dwellers. However, the empirical evidence for the proposition that the characteristics of the local environment to which an observer adapts throughout the life-span play a causal role in explaining the existence of the illusion was at best equivocal (Berry, 1968, 1971; cf. Goh et al., 2007). Yet, the variability in susceptibility to illusions between cultures was not in dispute and has been verified in more recent work (e.g., de Fockert, Davidoff, Fagot, Parron, & Goldstein, 2007; Ji, Peng, & Nisbett, 2000; van der Kamp, Withagen, & de Wit, 2013). Interestingly, recent work has attributed the cross-cultural differences to the relative degree to which individuals from different cultures visually attend to the focal object or more broadly including an object’s surround (de Fockert et al., 2007; Nisbett & Miyamoto, 2005), which—under the assumption that there is a relation between information detection and gaze behavior—may suggest the pickup of different optical variables between cultures (van der Kamp et al., 2013; van Doorn, van der Kamp, de Wit, & Savelbergh, 2009). For example, when presented with pictures of objects embedded in scenes, Westerners make longer fixations on the focal object, whereas East Asians make more saccades to its surround (Chua, Boland, & Nisbett, 2005). Consistent with this finding, Westerners show a reduced illusion bias compared to East Asians (Ji et al., 2000; van der Kamp et al., 2013).

A second source of variability in susceptibility to illusions is perceptual experience. Among Western children, an increase in sensitivity to geometrical illusions with age has repeatedly been observed (e.g., for the Müller–Lyer illusion: Brosvic, Dihoff, & Fama, 2002; for the Ebbinghaus illusion: Doherty, Campbell, Tsuji, & Phillips, 2010; Kaldy & Kovács, 2003; Weintraub, 1979; cf. Duemmler, Franz, Jovanovic, & Schwarz, 2008). These age differences suggest intra-individual variability, but the cross-sectional design of these studies does not allow for a definitive conclusion. However, there is a wealth of evidence showing that perceptual experience reduces susceptibility in adults to illusions (e.g., Eysenck & Slater, 1958; Judd, 1902; Predebon, 2006; Schiano & Jordan, 1990). In fact, two recent ecologically inspired studies have shown that repeated presentation of (variants of) the Müller–Lyer illusion with error feedback not only diminishes the illusionary bias, but likely induces a shift in the pickup of optical variables. That is, some participants (but not all) were found to attune to a length-specifying variable after having received feedback (Jacobs, Ibáñez-Gijón, Díaz, & Travieso, 2011; van der Kamp et al., 2013).

A final intriguing observation is the differential intra-individual susceptibility to illusions reported in the context of Müller and Goode's (1985) proposal that the perception of objects and the visual control of actions directed at those objects engages two anatomically distinct visual systems (i.e., vision for perception and vision for action). In a typical experiment in this research area, participants perform perception (e.g., for example, matching the aperture between finger and thumb to the size of objects) and action responses (e.g., for example, grasping with the finger and thumb) upon three-dimensional objects embedded in geometrical illusions such as the Müller–Lyer illusion (e.g., van der Kamp, de Wit, & Masters, 2012) or the...
Ebbinghaus illusion (e.g., Aglioti, DeSouza, & Goodale, 1995). A meta-analysis of 18 independent studies using the Müller–Lyer illusion indicated that finger aperture was largely unaffected by the Müller–Lyer illusion in grasping tasks but not in matching tasks (Bruno & Franz, 2009). This evidence has been extensively criticized over several methodological shortcomings; however, Stötinger and colleagues (Stötinger, Aigner, Hanstein, & Perner, 2009; Stötinger et al., 2012; Stötinger, Soder, Pfuisterschmied, Wagner, & Perner, 2010) reported a series of studies that were designed to satisfy these shortcomings. In line with Milner and Goodale’s proposal, Stötinger et al. (2009, 2010, 2012) found a significant illusion bias for matching but not for grasping.

The reviewed empirical evidence suggests that the pictorial displays that make up geometrical illusions contain optical variables that specify their size. Critically, this implies that susceptibility to illusions is not (always) necessarily a consequence of “inadequate” or unavailable information (cf., for example, Turvey et al., 1981), but rather that the optical variable that is specific to the property of interest to the observer is not always detected or exploited. Interestingly, the inter- and intra-observer variability in susceptibility to visual illusions is in line with Gibson’s insights; there is both inadequate information and adequate or specifying information present in illusory pictorial displays and what is perceived depends on the information to which the observer directs his or her attention.

The fact that observers exploit optical variables that are not specific to the property of interest—while specifying variables exist and are accessible—does not accord well with the general Gibsonian conception of perception as the detection of specifying information. Indeed, if observers sometimes rely on inadequate information, their perception is not always informed by specifying optical variables (see Withagen & van der Kamp, 2010). However, this does not entail that visual perception is sometimes dependent on (incorrect) inference and hence indirect. The next section will elaborate this argument, based on Withagen and Chemero’s (Chemero, 2009; Withagen, 2004; Withagen & Chemero, 2009) evolutionary motivated theory of direct perception which asserts that observers can perceive the environment directly by relying on both specifying optical variables and inadequate-, or what they denote non-specifying optical variables.

5 Participants were required to match and grasp objects that were embedded in the Parallelogram illusion and the Empty Space illusion (i.e., the distance between two points appears shorter than the same distance filled with a series of dots). The use of single target-objects ascertained that attentional demands for the matching and grasping tasks were appropriately matched (see Franz, Gegenfurtner, Bülthoff, & Fahle, 2000). Furthermore, vision of the hand was blocked (up to the time that finger aperture was measured), such that online corrections through a direct comparison of finger aperture and object size could not be made (see Bruno & Franz, 2009). This was done in both the matching and the grasping task to ensure that the available visual feedback was matched between tasks. Finally, unlike the hand, the object was continuously visible so that both matching and grasping were not memory-based (see Westwood, McEachern, & Roy, 2001).

5. Reconciling visual illusions with direct perception

Over the last couple of years, Chemero and Withagen have developed Gibson’s theory of direct perception, placing his conjecture that observers can pick up different optical variables in the ambient energy array central to their approach. These authors were primarily inspired by Gibson’s attempt at naturalizing perception. Indeed, in developing his ecological approach Gibson (1966) complained that “[t]he classics of vision were unaffected by evolutionary considerations or by knowledge of animal behavior but nevertheless they dominate the theories of perception” (p. 155). Withagen and Chemero (2009) argued that if perception is to be considered as an evolved biological function, one should expect variation between members of a population in what variables are picked up for a certain task. After all, and among other reasons, variability in a population is a necessary prerequisite for natural selection to take place. Furthermore, Withagen, (2004; Withagen and Chemero 2009) argued that, given the existence of constraints on evolutionary and developmental processes, sometimes the perceptual system that is required for the detection of a certain specifying variable cannot develop. Hence, a non-specifying variable—that is, a variable that is not specific to the property of interest—could in some cases be the best variable available to an observer to accomplish a certain task. Notably, the empirical literature on visual illusions that was reviewed in the previous Section is in keeping with Withagen and Chemero’s (2009) theory.

For our present purposes, Withagen and Chemero’s (2009) reconceptualization of direct perception is of special interest. Their evolutionarily motivated approach necessitated a reformulation of this concept such that it allows for the occurrence of perceptual inaccuracies. As we have seen, although Gibson (1966) argued that “inadequate” information exists, he fundamentally defined information in terms of specificity—a pattern in the ambient energy array is information for the perception of an environmental property only if it relates one-to-one to it. However, numerous studies on perception, action, learning and development have casted doubt on this conceptualization. Indeed, as we have seen in the empirical literature on visual illusions, observers often rely on an optical variable that does not specify the to-be-perceived property, yet it seems undeniable that they still have an experience of this property. When looking at for example the Müller-Lyer configurations, observers typically perceive the lines to be of different lengths, indicating that they rely on a non-specifying variable. Apparently, optical variables in the ambient energy array that do not specify an environmental property can, albeit inadequately, still carry information for perceiving it.

Chemero (2003, 2009) recently developed an ecological conception of information that accommodates this observation. Drawing on the work of Barwise and Seligman (1994) and Millikan (2000), he argued that patterns in
the ambient energy array that correlate with (rather than specify) the environment still carry information about the environment. According to Chemero, information is not contingent on specification relations (i.e., one-to-one mappings) between the ambient energy array and the environment but on constraints. That is, pattern X can carry information about environmental property Y if a constraint holds between X and Y. Central to Chemero’s conception of information is that this constraint can be a law (following, e.g., Turvey et al., 1981), but it can also be a regularity or a convention. That is, the connecting constraint does not have to hold without exception (granting a one-to-one relation), it can also hold probabilistically in that X is sometimes present when Y is not, and vice versa.

Imagine, for example, the optical variables that are available in the pictorial display that makes up the Müller–Lyer illusion. Observers might “isolate the two line segments”, as Gibson (1966, p. 313) put it, and thus rely on an optical variable that specifies physical length, explaining the absence of the illusion. As indicated by the experimental literature observers can indeed exploit such a variable. However, in most cases observers exploit an optical variable that is not a single-valued function of physical length but is co-determined by the wings and arrowheads. Although such a variable does not specify the physical length of the object, it is partly determined by it, allowing the variable to carry information for perceiving length. Interestingly, the detection of such a non-specifying variable can explain the illusion—indeed, there is a one-to-many relation between physical length and the optical structure. Although the length of the two lines in the Müller-Lyer figure is the same, the value of the optical variable is different for the two lines because of the wings and arrowheads. Hence, the two equal-length line segments are seen as having different lengths when such a variable is exploited. Specifying optical variables (i.e., that are not co-determined by the wings and arrowheads), on the other hand, relate one-to-one to the to-be-perceived property, rendering such perceptual inaccuracies absent when detected.

One might wonder whether Chemero’s conception of information does not lead to a Brunswikian theory of perception. Indeed, Brunswik (1956) had argued that the stimulus information available to the senses relates probabilistically to the environment, and, thus, is not trustworthy. This means, he suggested, that we have to infer the cause of the stimulus information to come to a perceptual judgment of the environment. Partly because of recent experimental demonstrations of the detection of non-specifying variables (reviewed in e.g., Withagen & van der Kamp, 2010), several authors who are sympathetic to the Gibsonian approach have suggested that this approach should be integrated with the Brunswikian theory of inferential perception (see e.g., Kirlik, 1995, 2009; Vicente, 2003). Kirlik (2009), for example, stated that “[r]ecent psychological research aimed at determining whether dynamic event perception is direct or mediated by cue-based inference convincingly demonstrates evidence of both modes of perception or apprehension” (p. 376). However, Withagen and Chemero (2009) did not agree with this conclusion. In their view, the detection of non-specifying variables does not entail inferential perception as suggested by Brunswik (see also Chemero, 2009; Withagen, 2004; Withagen & Chemero, 2012):

Consider, for instance, the bird’s perception of clear flight paths. The informational variable used by birds to perceive such paths may have been specifying throughout most of the course of the evolution of flight. However, the trustworthiness of this variable changed when humans invented nearly transparent glass, entailing that birds now sometimes crash into windows. Although the presence of windows changed the adaptiveness of the bird’s flying behavior, we believe that it is quite improbable that it implied a significant change in the nature of the perceptual process. That is, the abundant use of windows did not entail that the bird changed from a direct perception to an indirect perception of flight paths, meaning that the bird all of a sudden made inferences on imperfect information. Instead, the bird’s perception is, we believe, still the result of a direct pick-up of information.

Withagen & Chemero, 2009, p. 381.

To account for differences in the adaptiveness of perception, Withagen and Chemero (2009) suggested a continuum of epistemic contact—that is, the perceptual grip of the animal on its environment can differ in degree. In the development of this idea, they (2008; see also Withagen, 2004) followed Gibson (1979/1986) in conceiving perception as the activity of “keeping in touch with the environment” (p. 239). However, contrary to Gibson (see e.g., Gibson, 1959, p. 464; see also Shaw et al., 1982), Withagen and Chemero claimed that such an epistemic contact with the environment is not contingent on the pickup of specifying optical variables. Indeed, an epistemic contact is also established when non-specifying optical variables are picked up from the ambient energy array. More precisely, Withagen and Chemero (2009; see also Withagen, 2004) asserted that the strength of the perceptual grip on the world depends on the usefulness of the variable detected. To return to their example of birds and the perception of clear flight paths:

The informational variable that the bird uses to perceive flight paths may no longer specify that property. However, that does not mean that the bird is deprived of a direct perceptual touch with the environment, perceiving it via a representation. Rather, the bird’s grip on the environment is weakened. Still, its connection with the environment is better than a bird that is blind or uses other variables. This allows a continuum of cases of direct contact with the environment: the bird that uses a variable that is specific to actual open flight paths to guide its flying behavior has better contact with the flight-relevant features of the world than the bird that uses a variable that is ambiguous between open paths and windows; both birds will be in better contact than is a bird that flies into brick walls when it uses a variable to try to perceive paths.

Withagen & Chemero, 2009, p. 381.
In other words, when a specifying optical variable is detected, the epistemic contact is perfect, but this contact weakens when the exploited variable correlates less with the to-be-perceived property, that is, is less useful. This idea of a continuum of direct epistemic contact is a slight alteration of Gibson’s conception, but one that makes it more compatible with both evolutionary considerations and with the empirical data. It states that in the processes of evolution, development and learning, observers are in continuous epistemic contact with the environment, but that the strength of their grip on the environment improves when informational patterns are discovered that correlate more highly with the property of interest.

This account of direct perception explains the above-described inter- and intra-observer variability in susceptibility to visual illusions. Whether observers detect an optical variable that specifies length of line or a variable that merely correlates with this property, in either case they are in direct epistemic contact with the length of the lines. However, the epistemic grip on the world differs for observers depending on the informational pattern that is attended to; the observer who exploits the specifying pattern being in perfect touch with the world (and thus immune to the illusion) and the observer who detects a non-specifying variable having a lesser grip on the world, as indicated by the presence of the illusion.

6. Concluding remarks

Indirect perceptionists have typically argued that visual illusions reject the theory of direct perception in favor of a theory of indirect perception (e.g., Fodor & Pylyshyn, 1981; Gregory, 1966, 1997; Rock, 1997; Ullman, 1980). This paper shows that a theory of direct perception can account for illusions. Although neo-Gibsonianians have sometimes been criticized for explaining illusions away (see e.g., Cutting, 1982, p. 210), we have followed Gibson (1966) in that “[a] ny account of the facts of perceiving must include the facts of error” (p. 287) and “a concept of information is required that admits of the possibility of illusion” (Gibson, 1979/1986, p. 243). We have shown that Gibson’s account of illusion has been corroborated by the experimental literature—illusions can be accounted for in terms of the optical variables attended to. Yet, these studies cast doubt upon the Gibsonian conception of perception as the detection of specifying information.

To overcome this conceptual problem, we relied on Wihagen and Chemero (2009) in developing our ecological approach to visual illusions. These authors asserted that perception should be conceived of as an evolved biological function that can differ in degree of adaptiveness. Indeed, their account is primarily a theory of the individual differences in adaptiveness of perception and action that explains these differences in terms of the usefulness of the detected informational patterns. Susceptibility to visual illusions, then, is the result of the detection of a non-specifying optical variable, a variable that correlates with the to-be-perceived property but is not specific to it. The detection of such an optical variable gives rise to a weakened, but nevertheless direct epistemic contact with the environment.

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